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SYMPOSIUM ON INDUSTRIAL MEDICINE

INTRODUCTION

The ability of industrial physicians to reduce time losses from sickness and injury gives them a place of much importance in the war program. However, the available supply of experienced industrial physicians is limited—in fact, exhausted—and managements of war industries are of necessity employing general practitioners on either full or part-time basis.

Though competent physicians, these recruits are seeking instruction in order that they may apply successfully their medical knowledge to industrial service. Medical societies and medical schools are responding with short postgraduate courses and seminars.

As a supplemental means of instruction, the publishers of this book have made their pages available for this symposium on medicine in industry.

Because of the excellent quality of the papers, this issue of the Medical Clinics of North America becomes in reality a seminar for the doctor who wishes to prepare himself for the opportunity of industrial service, as a war effort, or the industrial physician who wishes to study as he works.

It is sufficiently comprehensive for reference and perhaps has almost attained the status of a book on industrial health. I am proud to have had a part in assembling this material and I take advantage of the opportunity to thank the distinguished contributors.

C. D. Selby, M.D.,
General Motors Corporation

The Medical Clinics of North America
July, 1942.

THE PHYSICIAN IN INDUSTRY

CARL M. PETERSON, M.D.*

PRACTICAL experience has amply demonstrated that industry needs the doctor and that the doctor needs industry. Certainly, the worker should expect to reap substantial benefits in improved health and earning capacity wherever industrial medical service is competently and fairly administered. Successful application of any kind of medical service rests fundamentally upon the best interests of the individual patient, a principle which is as reliable in industry as it has always proved to be in community practice. The purpose of medicine in industry, then, is to promote the health and physical well-being of every employee. The means for accomplishing this praiseworthy objective lie in three principal directions:

1. Prevention of disease or injury in industry by establishing proper medical supervision over industrial materials, processes, environments and workers.
2. Health conservation of workers through physical supervision and education.
3. Medical and surgical care to restore health and earning capacity as promptly as possible following industrial accident or disease.

Large industry has to a considerable extent recognized the value of these services and has taken steps to avail itself of them. Small and medium sized plants have considered themselves unable to support a medical program beyond the medical or surgical management of conditions for which industry is accountable under the workmen's compensation statutes. Actually, adequate industrial medical service, mainly preventive in character, is greatly needed in this class of establishment, the more so since it is unrealized and since unfavorable sickness or accident experience bears no relation to the num-

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ber of workers employed. These needs, already existent or latent, as the case may be, offer a genuine opportunity for medical accomplishment. The Council on Industrial Health believes that expansion of medical service into industries should be encouraged and controlled through an educational service which will:

1. Convince employers and workers alike, that medical service in industry merits support only if soundly organized economically, scientifically and ethically.
2. Acquaint physicians with the special character of industrial medicine, surgery and hygiene, and the necessity for the enforcement of standards defining scope and professional competence.

It is, therefore, insufficient to delineate medicine's value to industry in terms of major objectives alone. If a physician is attracted to industrial practice, with a view towards contributing to improved physical welfare of workers, it must be in accordance with well-defined and specific functions. Some plan of organization must be brought within the grasp of a practitioner, who at best can devote only part of his time to industrial service. Moreover, this plan should be readily adjustable to the accepted patterns of ethical, progressive community practice. The Council on Industrial Health has given much thought to a program of this character. It has, therefore, constructed *An Outline for Procedure for Physicians in Industry*, in which the objectives enumerated above have been expanded into a series of recommendations defining in some detail the duties of physicians in industry as well as new relationships which go to make up the principal alterations in professional approach between private and industrial practice.

Medical and Surgical Care

The earliest and still most commonly encountered requirement for medical service in industry is for competent management of the individual worker suffering from *compensable* illness or injury. As a rule there is little disposition by employers to assume any responsibility for treatment beyond this point. Since this relationship represents the principal point of contact between industry and the physician, it is

well to recognize at once that the ideal result is one which restores the disabled worker to his former earning capacity in the same line of work without unnecessary delay. As has already been indicated, a real distinction must be drawn between treatment of compensable as against non-compensable disability.

Treatment of injuries or diseases not industrially induced is a responsibility of private medical practice from which the physician in industry should abstain. The principal exceptions refer to minor ailments which temporarily interfere with an employee's comfort or ability to complete a shift, and urgent sickness occurring during working hours upon the working premises. Such situations demand attention by the physician in industry until notification of the family physician relieves him of further responsibility.

The industrial physician may also very properly assume responsibility for rehabilitation after disability in those patients who readjust best under controlled working conditions. The medical profession contends also that a worker disabled in industry should be free to choose his physician from all those licensed doctors of medicine competent to supply the regular services except where a third party has a valid interest or intervenes.

Prevention (Preventive Industrial Medicine)

The physician in industry, if present trends continue, will assume more and more the status of health officer to the plant. Recognition and control of *unhealthy* or *unsafe industrial situations* is the dominant factor which establishes the physician's value to improved industrial operation. He must, therefore, acquaint himself by regular inspection with all materials and processes used in the working environment over which he has supervision to the end that he may recommend proper protection of employees from conditions actually or potentially harmful.

In like manner, *physical examination* has come to be looked upon as an essential procedure in industry to assure safe placement of workmen and provide protection against diseases originating in or unfavorably influenced by occupa-

tion, and also to establish the occupational or non-occupational origin of disability. Without this prop to lean upon, medical service in industry is very considerably handicapped. To fulfill their requisite function, placement examinations should be reasonably complete and should be used only for the purpose of assigning work adjusted to the physical ability and mental aptitude of applicants and to maintain safe and healthful employment for all workers. Subsequent physical examinations should be complete enough to provide positive health protection for all workers and to safe-guard public welfare. Records of these examinations are confidential and access to them should be granted only upon request or consent of the examinee. He should be informed of the results of examinations and steps should be taken to refer conditions needing correction to the physician of the worker's choice.

Health Conservation

These same recommendations in respect to physical examinations are equally applicable to a program of health conservation. Based on his own findings, the physician's recommendations can supply much needed instruction to workmen about healthful living both in and out of the industrial environment.

Other Relationships

Many factors, social and economic as well as medical, tend constantly to modify these principal relationships of the physician in industry. There must be suitable adjustment with the employer, the employees, professional aides like nurses and first-aid men, with consultants and official agencies. The unmistakable tendency, however, is to rely on *prevention* as the cardinal principle for reducing lost time and increasing earning power among employees. Further expansion of medical service to industry on any considerable scale will depend squarely on the ability of the individual practitioner to grasp this concept. If this status is realized, there will be gradual but steady reduction in remedial service now supplied in one or another of the provinces of industrial medicine and traumatic surgery. Many physicians in industry

have already amply proved their ability to provide more and better preventive medicine by employing the methods, equipment, and special information usually classified under industrial hygiene and industrial health administration. It is through such measures that the best interests both of those who supply and those who receive these services will be most fittingly realized.

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ORGANIZATION AND MANAGEMENT OF AN INDUSTRIAL MEDICAL SERVICE

A. L. BROOKS, M.D.*

MEDICAL activity at the Fisher Body Division of the General Motors Corporation was begun just before our entry into World War I. Of course, at that time, many of the plants now in operation had not been built. What is now a great Division was then a small Corporation. There was little standardization of medical service as it came into being. Improvements had to be made on the basis of trial and error. But there were at the head of the business men who were deeply interested in the welfare of every employee. They knew the workers by their first names; they worked with them, knew when they were sick, injured, or in trouble; and they generously approved every reasonable effort that was put forth on their behalf. Without this support, progress would have been impossible.

Many modifications in the medical service, however, were brought about by changes in the products built, the materials used, the mechanical processes, by legal requirements relating to accidents and occupational diseases, and finally by a broader conception of the principles of preventive medicine and what we may term "Industrial Public Health." There are now more than a score of manufacturing units distributed from coast to coast. The medical departments of these are under the direct supervision of twenty-four physicians, all but three of whom are on a full time basis. There are seventy-five registered nurses and a dozen male attendants besides x-ray technicians and the necessary number of record clerks.

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libraries, and other industrial concerns which have had helpful experiences. The doctors (as a group) may be said to be self-educated men in matters of industrial medicine. If they have missed some of the finer points which we hope may one day be more generally available, they have developed along practical lines and have been guided by sound principles.

The physicians are successful in the degree that they possess ambition, imagination, interest in the employees and willingness to cooperate in furthering the success of the enterprise. Some of them have had to forego to some extent the opportunity to advance in the specialties in which they may once have had a special interest. This is particularly true in surgery which has become relatively less important as safety efforts have curbed accidents.

On the other hand, with this change has come a broader conception of the opportunities in preventive medicine. This trend has grown slowly but it is advancing on a very secure footing.

The Nurses and Record Clerks

The industrial nurse is the object of considerable attention at this time. The nursing organizations have been active in outlining her qualifications and making suggestions for guidance in her activities. Gone are the days when a nurse was assigned to plant medical work because she happened to be a relative or friend of the superintendent's family. She is chosen by the physician if and when she can satisfy him that she possesses the qualities needed—education, professional training, good health and habits, and either proved ability in the industrial field or promise of attaining that ability. Few of them are experienced in industrial medical work when first employed. In fact, industrial experience is not heavily weighed in most instances.

An intelligent, well trained nurse should begin to be valuable to the department at the end of the first month. She continues to improve as long as she remains in this kind of work. She realizes that she carries the same responsibility as any other nurse in relation to caring for ill or injured

NATURE OF MANUFACTURING PROCESSES

Some of these plants work a single eight-hour shift daily while others have two or three shifts. Prior to the outbreak of the present war they were engaged chiefly in fabricating steel panels and other structural parts, or the upholstery of automobile bodies. One plant made all the hardware while several were essentially assembly units. Other plants built the tools and dies. Still others were engaged in research and experimental work only.

There were stamping, welding, painting, grinding, polishing, plating, and sewing processes, together with a great many others of equal importance. Likewise there were exposures to heat, electricity, high speed machinery, and solvents as in any other similar industry. To control these exposures, hundreds of thousands of dollars are expended annually to provide proper heat, ventilation and light, to guard machines, to educate the employees in safe practices, to afford personal protection by the use of respirators and goggles. In this work the medical department has a direct interest, and the object always is to provide for the employees safe and wholesome places in which to work.

PERSONNEL OF AN INDUSTRIAL MEDICAL SERVICE

The Doctors

The system as it stands today may best be considered under the main heads of *personnel*, *equipment* and *operation*. As mentioned above, all but three of the physicians devote all their time to the units which they serve. Some of them had been engaged in private practice before taking up industrial work, while others are young men who, because of special interest in industrial medicine have gone directly from hospital connections to our organizations, usually beginning as an assistant to one of the more experienced physicians and then being transferred as new units are opened up or as other changes are made.

Most of these men have not had the benefit of any extensive special courses in industrial medicine. They are, however, located generally in cities where there are abundant sources of information such as medical schools, universities,

libraries, and other industrial concerns which have had helpful experiences. The doctors (as a group) may be said to be self-educated men in matters of industrial medicine. If they have missed some of the finer points which we hope may one day be more generally available, they have developed along practical lines and have been guided by sound principles.

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An intelligent, well trained nurse should begin to be valuable to the department at the end of the first month. She continues to improve as long as she remains in this kind of work. She realizes that she carries the same responsibility as any other nurse in relation to caring for ill or injured

employees, and in addition, like the doctor, she acts as a representative of her employer in promotion of the right employer-employee relations.

Our observation of contacts between workmen and nurses convinces us that in practically every case there is a feeling of confidence in and respect for the nurse. When this relation does not exist, steps are taken immediately to determine the cause, and correct the condition.

All excepting the smallest units require the services of one or more *record clerks.* These are usually girls who have special training. They have to become familiar with medical terms which is no small accomplishment. They must know how to get the right information from the employees, set it down, and keep all records filed so that years afterward they may be brought out if required. They must know how to handle sick, tired, and injured men. A good receptionist may be a deciding factor in the question whether men will be willing to patronize the hospital when they should or avoid it as a pestilence.

QUARTERS AND EQUIPMENT

We are guided in our selection of quarters and equipment by the same principles that have found favor in the Army. That is, we must have sufficient space in a well chosen location, and we must have suitable medical and surgical furniture, instruments, and drugs, and substantial and convenient office equipment—nothing more. We believe that fancy gadgets have no place in industrial medical departments.

Location.—The quarters should, if possible, be on the first floor. This is for the obvious reason that most employees are found on the lower floors of the plant, as a rule, because of practical manufacturing economy. Then, too, the trend is more and more in the direction of one-story plants. Certain administration offices function best when detached from the activities of the bulk of the employees, but not so with the medical department. There is but one objection to having the medical unit close to manufacturing, and that is the noise and vibration that goes with most such activities. If this is excessive it is well to have one well isolated room for special

examinations. A room that is almost completely sound proof was obtained in one of our plants by the simple expedient of constructing eight inch insulated walls, ceiling and doors. It is used often to great advantage.

Employees should not be asked to cross a busy street to reach the medical unit because of exposure to traffic hazards. Any considerable distance out of doors would also be objectionable on account of exposure to inclement weather. Then, too, there are always a few men who might take advantage of a long trip to the hospital as a means of an extended period of relaxation and recreation and the pleasant but none-the-less unnecessary solace of the "weed."

Floor Space.—We know there is a certain irreducible minimum with regard to floor space. The plant of 1000 employees will not require as much space as that having 5000, but it will require probably half as much. If both men and women are employed, there will be need of more space for their segregation in both examination and treatment. Employees tend to congregate and compare notes and become unduly concerned with their neighbor's woes, but a few private dressing rooms tend to prevent this besides affording great satisfaction to those who desire to keep their affairs to themselves. Our eye cases are never treated in a general treatment room but in a small, quiet room which can be darkened and kept scrupulously clean. Likewise, no infected cases are ever allowed in the small operating rooms where we may have occasional tenorrhaphies or amputations.

Ultraviolet, infrared, and diathermy treatments are often done in rooms used at times for general examinations and treatments. Probably 80 per cent of all cases, both surgical and medical are handled in the large general dressing rooms without embarrassment. This makes for faster and more efficient work. These general rooms are usually about 20 by 30 feet. If smaller, we experience crowding, but if too large, there is an unnecessary amount of travel on the part of the attendants.

Arrangement of Quarters.—We have tried out two general plans of arrangement in the larger plants, one in which there is a long corridor, flanked on either side by small specialty

rooms, and the other in which the large, general treatment room is surrounded on all sides by the smaller rooms. In general, the latter is the favored plan where possible. The former, however, does give us a maximum of natural lighting and ventilation when ranged along the outside of the building as they always are.

Floor.—We have very definite convictions regarding the type of floor that is desirable. We avoid if possible the tile or other hard floors because they needlessly tire the attendants. The heavy rubber tile, usually laid in squares from six inches to a foot in dimension, generally dark in color but irregularly mottled with a second color, are noiseless, comfortable to stand on, easily cleaned, do not show grease smudges from employees shoes, and present no skid hazards to the men on crutches.

General Remarks.—*Partitions* are best built up of metal panels although opaque glass is often used to secure improved lighting. *Good air* is provided in some units by having high ceilings and lower partitions except when greater privacy is required as in the doctor's office where consultations may be held. In the general treatment room, the men are seated while being treated. If the hand or arm is involved, the member is laid on a *white enameled table* 16 by 40 inches, the attendant standing on the opposite side from the patient. A *dressing cart* at the attendant's side carries an assortment of supplies that are usually sufficient, and adhesive in various widths is pulled off spools attached to the table. Substantial equipment made by reliable houses which was bought twenty years ago is still in use and has depreciated scarcely at all in appearance and value. *We are convinced that bargain counter equipment has no place in our medical departments.*

X-ray equipment capable of producing good chest films with an exposure of one-tenth second are used. We have not as yet adopted the photofluoroscopic method for the reason that we believe we might wish to make so many checks on the small films that numbers of the larger ones would be used and thus not reduce the cost. Storage of the large films has been no serious problem in our plants, even those which employ up to 10,000 men.

We do not regularly have equipment for doing electrocardiographic and basal metabolic work because conditions requiring this would be of a medical nature and should properly be the field of the nonindustrial internist.

OPERATION OF THE MEDICAL DEPARTMENT

The *plant doctor* in every case is responsible for the operation of his medical department. He generally answers directly to the resident manager, or occasionally to the personnel director who has charge of employment, insurance, safety.

Fig. 152.—Getting data for a record.

welfare, compensation and allied interests. There is a *medical director* at the home office whose function is to correlate, standardize, and integrate the activities of the various units. In this way, any success that is achieved in one place may be passed on to others. Studies of occupational exposures are arranged by the central office.

Of necessity, in most of the units, the doctor cannot see all the patients himself at each visit. Therefore, standing orders are employed by which nurses may be guided. If

there is any question in the nurse's mind, the doctor's advice is asked. Even in apparently simple cases it is a general practice for the nurse not to treat a patient more than once before the doctor's attention is called to his case.

Physical Examinations

In discussing the operation of the medical department, it seems logical to begin with physical examinations. We list four types of these as pre-employment, periodic, occupational, and casual.

Fig. 153.—An important matter.

The *pre-employment examination* is somewhat more thorough than it was a few years ago. The routine calls for a vision check by means of Snellen chart, projection, or one of the now popular optical instruments which gives somewhat more information than the previous methods. Head and neck, chest, heart, blood pressure, extremities, are done in the usual manner, followed in new employees by chest x-ray, urinalysis, and Kahn test. The station and gait are noted, and

casual conversation usually throws some light on the personality. The vision check, x-ray, and urinalysis are usually done by an assistant while the remainder of the examination is done by the doctor.

The whole procedure requires something like twenty minutes per man. The findings are noted on a 5 by 8 inch card which has sufficient space for six examinations. A positive Kahn is always repeated. If it remains positive the appli-

Fig. 154.–Is he eligible for employment?

cant may be employed only if he has no clinical signs of syphilis and if he faithfully lives up to an agreement to bring proof that he is receiving adequate treatment regularly from his physician or clinic. Questionable chest plates are examined by a roentgenologist. If any conditions are discovered which should be treated, the applicant is urged to consult his physician, and should he be employed, the plant physician will continue to cooperate with the family doctor on his behalf.

The plant physician does not, himself, decide whether the candidate shall be employed, but advises the employment department as to his eligibility. Naturally, the relation of the physician and the employee being of a confidential nature, the details cannot be disclosed but sufficient information can be given to enable the employment manager to make a proper decision. A man may be employed who has certain defects which limit his activities. This information is relayed to the foreman so that he will not require him to do heavy or hazardous tasks.

The purpose of the pre-employment examination is not to reject the unfit, but rather to classify and place all employees on jobs where they will be successful and where they and their fellow workmen will be safeguarded. There has never been any objection on the part of the employees to such examinations. On the other hand, we frequently have expressions of gratitude when defects of which the men have no knowledge are brought to their attention.

Periodic examinations are designed for all employees who have worked so regularly without layoff, rehire, illness or accident that they have not had cause for examination for a year or more. These examinations are not done at exactly the termination of the first year but as soon as possible after the end of the year, the men being called in by departments.

Regular *occupational examinations* are done on all employees who are considered to be engaged in any work which involves unusual or harmful exposures. Examples of such would be fumes or dusts of the toxic metals, silica dust, and some of the solvents. These periodic examinations are made usually at monthly intervals, although in cases where the exposure is considered to be usually well controlled, the interval might be longer.

Casual examinations may be made upon the request of employees who desire the advice of the plant physician. Likewise, any man who has been off work because of illness or accident is examined before returning to work. The great number of these casual examinations reduces the need of periodic examinations.

Routine Duties

The routine work of the medical department includes the care of the injured and sick. We mention injuries first because despite a remarkable decrease in accidents over the past

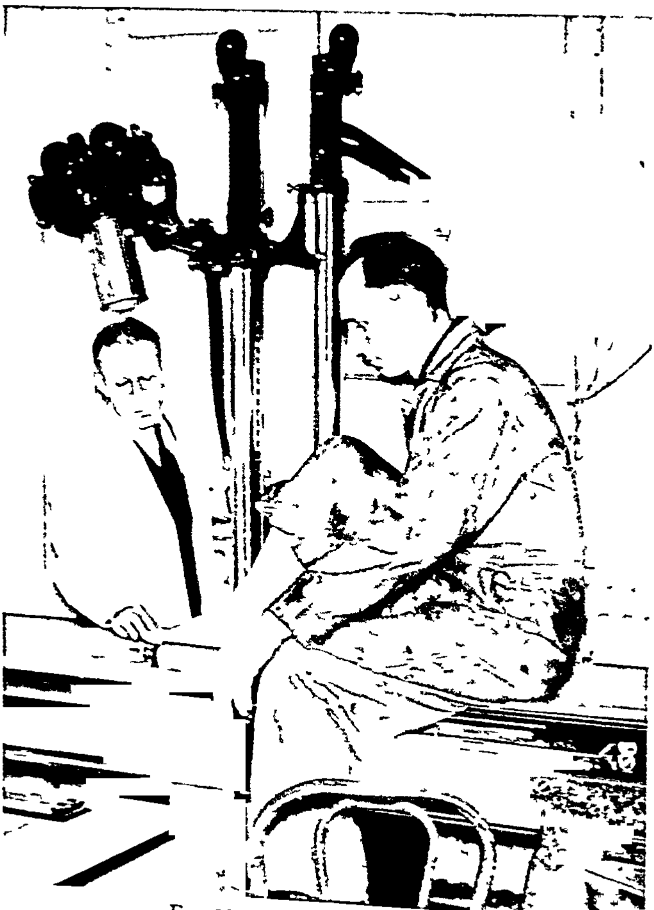

Fig. 155.—Is this foot fractured?

decade, there are still a great number of minor injuries which must be treated. In the early days of industrial medicine this was in some cases the sole reason for the employment of the doctor by the company. Thus, industrial medicine came to

be thought of as essentially traumatic surgery. The situation has changed to such an extent that the minor surgery done in the plants requires far less of the doctor's time than the medical work.

The greater part of the medical work consists of cases which are personal. The only excuse for their demand on the physician's time is that they are of such a minor and temporary nature that they would never reach the family

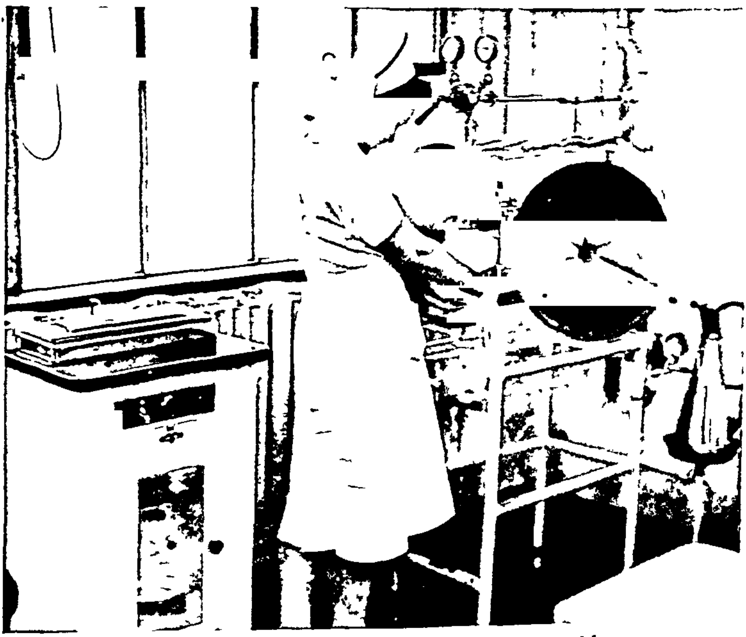

Fig. 156.–Equipment, though plain, is serviceable.

physician. It is easy to understand that an employee would consult a doctor if he had but to quit work a few minutes, and go into the medical department on company time and receive attention, without cost. Doubtless this privilege is often abused, but occasionally a condition comes to the attention of the doctor which is very important. A few words of advice and instructions to report immediately to his family physician may forestall serious sequelae.

There is also the *public health aspect of industrial medi-*

cine. Our physicians are charged with the responsibility of inspecting working conditions as heat, light, ventilation, and dust. There are available to all units the services of a department of industrial hygiene, maintained by the company, whereby dust counts and so on can be had upon request.

The doctor also keeps informed on possible *occupational disease exposures* and may collaborate with the State Department of Industrial Hygiene and, in fact, sometimes receives information from the bureaus of other states, the U. S. Public Health Service, and the National Institute of Health, and other authentic sources.

The doctor's examinations, both routine and casual, sometimes reveal infectious diseases which might, if unchecked, involve healthy persons. He works closely with the local Board of Health in reporting diseases, in following cases of tuberculosis, and in recommending vaccination. We believe that this activity is one of the reasons why statistics on non-industrial illness among our employees are considerably better than for the country as a whole.

Records are kept on all the activities of the medical department. These are necessary for the purpose of following health trends as modified by environment and are of particular importance to the safety department and the claims department. Most of the record work is accomplished during the day. During the second and third shifts, notes are made in pencil to be typed on permanent records the next day.

An active attendant on a busy shift may care for as many as seventy-five minor cases in eight hours. The less busy night shifts are utilized in part by the preparation of supplies. We have not employed visiting nurses although the doctor makes some house calls. Most of our physicians prefer to send their major surgery to able surgeons in their community. On the other hand, they have become most *proficient in minor surgery*, plastic repairs, and tenorrhaphies. These are done under local anesthesia at the plant hospitals.

The Industrial Doctor in the Present Crisis

As an example of the doctor's cooperation in affairs which are jointly the responsibility of industry and the community,

we cite the effort now being made on behalf of Home Defense. Here, the physician is in a particularly good position to render important service in case of a catastrophe in his plant or his neighborhood. To this end, first aid stations are being set up, extra supplies provided and plans made for segregating and transporting the more serious cases, and treating the minor ones. First aid squads are being recruited and trained for primary first aid work in the units. These squads will engage in rescue work and transportation to the plant medical department where appropriate care can be given.

Our doctors and nurses are on the alert. Some of them have joined the armed forces. The remainder are taking up the task of helping to provide the means of victory. There are no complaints, no feeling of self pity if the hours be long and the work hard. They are grimly happy to give their entire energy with that typical American spirit which guarantees success.

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PHYSICAL EXAMINATIONS IN INDUSTRY

GRANT L. BIRD, M.D., F.A.C.S.*

EXAMINATIONS carried out by an industrial medical service will vary greatly with the size and character of the industry, as well as the extent to which the executives of that particular industry propose to carry out a health program. In many small industries, and in some larger ones, this health program does not in reality include any medical service but is confined chiefly to the diagnosis and treatment of industrial injury, which belongs to a surgical rather than to a medical service. In any well-organized medical service provision should be made for physical examination of all employees. Physical examinations may be classed under pre-employment, periodic, and postsickness procedures.

1. PHYSICAL EXAMINATIONS—PRE-EMPLOYMENT

(a) Purpose

The advent of compensation laws making industry responsible for injury to employees has led to the inauguration of physical examinations for the purpose of ascertaining physical fitness and eliminating unnecessary costs which would result from the employment of poor physical risks. The advent of insurance and sick benefit schemes has likewise been a stimulant to physical examinations for the purpose of establishing the standing of employees as insurance and sick benefit risks. Both these reasons for examinations are perfectly legitimate. In any well balanced health program, however, the most important value of pre-employment physical examination is the direct benefit to the prospective employees, as these examinations draw attention to defects which may be improved by

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treatment or by preventive measures. Pre-employment examinations also assist in placing an employee at the type of work for which he may be best fitted and competent to carry out.

The standards of most, although not of all companies, prohibit the employment of certain applicants. The rejection of certain applicants may at first thought appear not to be serving the community fairly. On the other hand, careful investigation reveals that there is a direct purpose served, particularly to the applicant who, if employed, would be a menace to himself, to his fellow employees, or to property. Rejection of an applicant may not mean that he is unemployable. For the industry or the particular position concerned, however, it signifies that he is not a desirable employee. It is the duty of the medical examiner not only to find out if the applicant is a desirable employee but also to evaluate his physical condition and mental standing for job placement. In order to do this, the physician must understand intimately the industry and have a working knowledge of plant activities, job requirements, and hazards.

(b) Benefits

The benefits which accrue to *industry* from pre-employment physical examinations may be summarized as follows:

(1) The proper placement of employees tends to greater efficiency and greater safety.

(2) Unjustifiable claims for compensation, or insurance, for conditions which existed prior to employment are to a great extent avoided.

(3) Fellow employees are protected against contagious diseases.

(4) Loss of time from prolonged disability or illness due to preventable diseases or diseases which may be treated is definitely reduced both by rejection of undesirable employees and by placing under care those who may be improved by treatment.

(5) The pre-employment examination record is of specific value to the employer for future reference and comparison.

(6) The selection of applicants, physically suited for

their duties, materially reduces employment, training, and production costs.

The benefits or advantages accruing to the *individual* or prospective employee by the pre-employment examination may be summarized as follows:

(1) A carefully performed physical examination conveys to the prospective employee a sense of security and satisfaction in his job.

(2) Examination provides him with a knowledge of his physical disabilities, with which he may or may not be familiar. He may have an early diabetic or chest condition, etc., which by proper care may be quite amenable to treatment.

(3) The examination and its accompanying recommendation places him in a position which he should be able to fill adequately and safely, with greater profit to himself and to his employer.

(4) The carefully recorded findings of a physical examination may be of value to him for future reference in case of accident or of any insurance disputes concerning previous existing conditions.

(c) Methods

Physical examinations for employment should be carried out before there is any specific engagement or contract between the employee and the employer. Examinations made a few hours, a few days, or a few weeks after employment, and particularly after the employee has started work, are unlikely to prove satisfactory. If it then becomes necessary to decline further employment or to change occupation, it becomes embarrassing both for the employee and employer. This delayed procedure also defeats some of the purposes of physical examinations in that the employment training and the production costs have not been protected.

Many methods and routines for examinations are in use. Most of these obtain the same results. *It is advisable, however, for each medical service to establish its own routine*, endeavoring wherever possible to make use of lay assistants, eliminating wherever possible confusion and loss of time. The

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prevention of loss of time becomes a very essential factor in peak employment periods and in industries where the turnover of labor is large. The use of assistants such as nurses, male nurses, medical clerks, etc., in carrying out the preliminary portions of examinations is both quite permissible and time saving. The use, however, of assistants in making actual physical examinations should not be countenanced under any consideration. Physical examinations proper should be carried out only by adequately trained industrial physicians. Male and female nurses and well trained attendants, with adequate training, are quite capable of obtaining much of the medical history and completing certain preliminary examinations, as well as carrying out most laboratory procedures—thus permitting the physician to devote his time to the essentials of the physical examination which cannot be carried out by attendants. In the case of female employees, this preliminary work can best be done by a well-trained nurse. In industries employing a large group of female labor, thought may well be given to the employment of women physicians. Although women have not found a large place in industrial medicine, this is one phase of an industrial medical service which they cover extremely well, serving both the industry and the prospective employees much better in many cases, than does the average male physician.

Outline of Procedures.—The following outline of procedures is not necessarily a perfect one, but is one which has given very satisfactory results.

Preliminary Examination.—A prospective employee, making application for a position and having been found by the interviewer in the employment department to have the necessary qualifications, is provided with a simple form which requests a medical examination. This is sent with the prospective employee to the medical division. Here he is received by the medical clerk, or nurse, who by training is capable of obtaining considerable history and completing certain preliminary examinations, using the regular medical records of that industry, an example of which is shown in Fig. 157.

In this preliminary examination the applicant's name, ad-

dress, proposed clock number, proposed occupation, department, age, family history, record of past employment, illness, and injury are recorded. In certain types of industries a history of subjective findings of the various systems should be

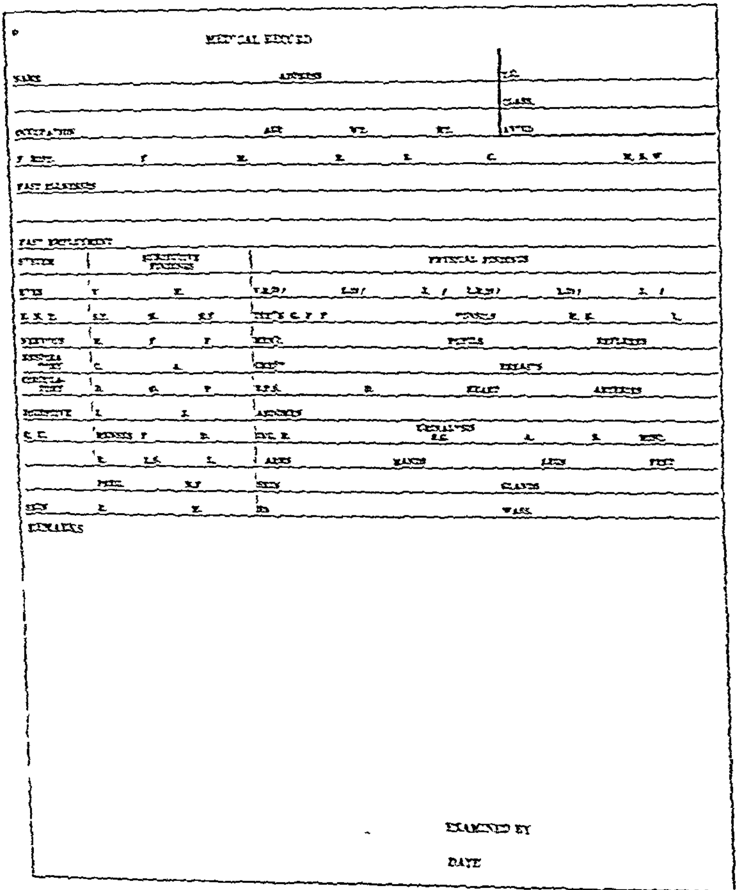

Fig. 157.—Sample of Medical Record.

specifically recorded. Subjective histories of many applicants who are anxiously awaiting employment are frequently of little value. This does not mean, however, that this study for employees approaching specific plant hazards should not be carefully taken, even though negative answers are given.

Good training of the nurse, or medical clerk, in obtaining this subjective history is quite essential, particularly in the use of a diplomatic approach by way of a well-planned questionnaire. The record of past employment and injuries is usually readily given and is often of real value.

The medical clerk, or nurse, then takes the applicant's weight, height, and vision with and without glasses. In obtaining the *vision* of prospective employees for duty as laborers in the construction trades, in the heavier mechanical trades, and line workers, the use of the Snellen cards and Jaeger near-vision cards, or lighted modifications of these, are probably the most satisfactory. For prospective employees for office duty, railway companies, aviation companies, precision duty as tool and die makers, chemists and mechanics, a more elaborate test such as that provided by the Keystone Telebinocular is advisable.

Applicant's Preparation for Examination.—The applicant is sent by the nurse, or medical clerk, to the dressing booths and requested to void a specimen of urine and to remove the desired amount of clothing. Male employees should be asked to disrobe completely. The female employees should be asked to remove all clothing except pelvic foundation garments and to put on gowns or some superficial covering which permits examination and yet relieves the embarrassment of the applicants. A simple type of covering for this purpose is readily made by two large bath towels, attached by safety pins over the shoulders. These are pinned before application and kept in readiness in the examining booths. They are quickly applied, quickly removed, and readily laundered. Suitable containers for the urine should be available. In the case of male employees the regular seven- or eight-ounce specimen bottles now commonly in use are very satisfactory. In obtaining routine specimens from female employees, in addition to the specimen bottle, an enamel 10-ounce graduate with handle and pouring tip is useful. A laboratory report record should be attached to the specimen and sent with it to the laboratory.

The *dressing booths*, numbering six to eight for each examining physician, should be so situated that there are two-way entrances, one leading from the medical clerk's or

nurse's office and the other to the examining room of the physician. The medical clerk, or nurse, may thus continually have a number in chain-readiness for examination purposes. The medical history is then placed at the disposal of the physician in the examining room and the prospective employee called from the dressing booth at the request of the physician.

The *examining room* to which the patient is admitted from the dressing booth should contain the following as a minimum: a desk (preferably high and suitable for writing in standing posture), an examining table or couch, two stools or chairs, instrument or utility table bearing sterilizers for syringes and similar instruments, thermometer, tongue depressors, flashlight, ophthalmoscope, otoscope, stethoscope, and sphygmomanometer, preferably wall type.

Examination Proper.—The physician, before making the examination proper, should review the preliminary history to familiarize himself with it and to be certain that it is reasonably complete. In many cases, further personal inquiry by the physician is advisable. By this further inquiry, too, the physician is enabled to estimate the applicant's mental status. The actual physical examination does not differ from other complete physical examinations. Therefore, details will be avoided. The *recording of objective findings* may be done by the physician directly, or by dictation to a clerk, or by the use of a dictaphone. As far as possible, all time-saving procedures should be adopted, such as using the blood pressure cuff as a tourniquet for the taking of blood following the blood pressure readings; using one specimen of blood for as many tests as are desirable, *e.g.*, flocculation tests, hemoglobin estimations, and so on. When routine chest films are being taken, they may be taken either before or after the physical examination, depending upon which routine is best favored by the chain procedure being carried out. Present day x-ray equipment, using the 35 mm. film or a 4 by 5 inch film, facilitates x-ray surveys of chests at a very low cost.

Consideration for Applicant.—Following the recording of objective findings, the physician may wish to wait for the complete record of laboratory and x-ray findings before clas-

sifying his applicant. More frequently, however, the classification is made immediately, subject to the necessity of alteration; the classification being placed on the medical form as well as on the form, "Request for Medical Examination," which is sent with the applicant back to the employment department. If, after due consideration, the examining physician classifies the applicant as unemployable, this should be carefully explained to him before he leaves the medical department, pointing out that he is not being declined employment of all description, but that for the particular job for which he is making application he is not physically qualified according to the standards of the company. If, because of some temporary disability, he is declined employment, a method of correction should be pointed out to him and information given as to when he should return for further examination.

If the applicant is found suitable for employment but has some disability which needs treatment, or requires correction, he should again be informed as to how this may be done and encouraged to carry it out. The examination record is retained in the medical department and filed for further use. It should remain as a confidential record for use in this department only. The reverse side of this particular form is used for reports of both subsequent examinations and accidents and sickness.

In conveying information to the employment department, it is always a good policy to give the classification *only*, without reference to the disability of the individual. Because of the possibility of later dispute, it may be necessary under the "B" classification to inform the employment department the type of work which should be avoided, for example, heavy lifting duties, specific hazards such as dust, lead, tetryl, T.N.T., and so on.

Time Element in Examination.—The routine examinations of urine can be done by a technician or a nurse trained for this routine duty, and is preferably done before the applicant is classified. The results of more elaborate laboratory work and x-ray reports must be awaited. The length of time required for the physical examination appears to be increasing as the years go by. A survey made by the National Industrial

Conference Board revealed an average of eight minutes in 1920, an average of ten to fifteen minutes in 1924, while in 1930 a large number of companies reported the use of thirty minutes or more. A recent check on the length of time being devoted in a large war industry revealed that one physician, assisted by a capable medical clerk, was examining five employees per hour. This included the taking of blood for hemoglobin estimation and for flocculation test. In the same industry, one physician and two nurses were found to be examining seven female employees per hour.

(c) Standards

Both for the purpose of classifying the employees and for the purpose of conveying information to the employment and production departments, it is necessary to have some standard of evaluating physical findings. The American Conference Board of Physicians in Industry formulated a classification of physical findings as follows:

Class 1—Physically equipped for any work.
Class 2—Physically underdeveloped or with some slight anatomical defect; otherwise fit for any work.
Class 3—Fit only for certain employment when approved and supervised by the medical department.
Class 4—Unfit for any employment.

The American College of Surgeons has likewise recommended a similar classification. Most industrial medical services which have been in operation for a period of time have adopted some modification of this classification, and if it is rendering good service to the industry there is no indication for alteration. The following classification is one used by the author over a period of years:

Categories

A 1—Physically fit for any work, with no defects found that are worthy of note.
A 2—Physically fit for any work but with minor physical defects that are worthy of note.
B —Physical defects, limiting employment to certain selected class of work.
C —Physical defects or diseases, making employment undesirable.

Explanation

A 1—As noted previously.
A 2—Physically fit for any job but with any of following defects:
Minor defects in vision, visual acuity of 20–40 or less in both eyes.
Visual acuity of less than 20–30 in one eye, less than 20–200 in the other, with suitable correction.
Minor defects in hearing.
Decayed teeth.
Pyorrhea.
Chronic tonsillitis.
Amputation of fingers, not more than two.
Youth.
Underweight.
Minor nervous disability.
Overweight, moderate.
Flat feet, no symptoms.
Varicocele.
Varicose veins, moderate.
Poor knowledge of language.
Mild kidney or bladder infection, under control.

B —Defective vision, one eye blind or seriously defective, 20–200 or less, or Jaeger 4, with or without glasses.
Defective hearing, unable to hear normal voice at five feet.
Chronic suppurative otitis media of one ear.
Goiter, nontoxic and postoperative.
Asthma or hay fever.
Tuberculosis, arrested with approval of attending physician.
Heart lesions, well compensated.
Varicose veins, severe.
Chronic kidney or bladder disease with abnormal function.
Hernia
Hemorrhoids with symptoms.
Amputation of limb with stump in good condition.
Bronchitis under control.
Convalescing after recent operation.
Diabetes under control.
Vascular disease, moderate.

C —Epilepsy or history of dizzy or fainting spells.
Vision in both eyes 20–200 or less, or Jaeger 4, with or without glasses.
Chronic suppurative otitis media of both ears.
Active kidney or bladder disease.
Discharging sinus of spinal column, leg, foot, if sinus leads to diseased bone.
Imbecility or insanity.
Goiter, toxic.
Venereal diseases, acute.
Alcoholism.
Tuberculosis, active.
Heart disease, decompensated.

Varicose veins, severe and untreated.
Drug addiction.
Pregnancy (late).
Cancer or malignant growth, untreated.
Diabetes, untreated.
Vascular disease, severe.

This summary serves as a guide in measuring the importance of physical defects of an employee represented by the category given him at his medical examination. It includes only a portion of the defects and disabilities that are encountered in examining applicants and is intended to serve simply as a basis of comparison in judging the importance of physical defects.

(e) Results

Using the classification outlined above, the table below records the distribution of three groups of pre-employment examinations:

	A-1	A-2	B	C	Total	C (Per cent)
1937 series ..	5289	2667	1262	124	9342	1.3
1941 series	3124	7092	3440	511	14167	3.6
Special series of moulding trades	347	145	29	32	553	5.7

In the 1937 and 1941 series no routine chest x-rays were done. In the special series for moulding trades all chests were x-rayed.

The following is a summary of disabilities necessitating Classification "B" in the 1937 series:

Vision	
Hernia	349
Diseases of chest	278
Diseases of bones and joints	43
Diseases of heart and circulation	111
Diseases of thyroid glands	75
Diabetes	7
Miscellaneous	6
Total	393
	1262

In the 1941 series, 8800 (approximately one-half female) bloods were examined by the standard Kahn test. Of these, 99 or 1.12 per cent gave positive reactions.

2. PHYSICAL EXAMINATIONS—PERIODIC

The medical service of an increasing number of industries arrange for periodic examinations of their employees. Although these examinations may not be frequent, they are just as important as are the pre-employment examinations. For the executives and officials they are of very specific value for the purpose of maintaining physical fitness and lengthening the span of useful life service. For the workmen, also, they are scarcely less important. It is of no less value to find, at the end of a three or five year period, that they are suffering from a diabetic or other condition which may be influenced or corrected by treatment than it was to find these same disabilities at the time of their employment.

The *frequency* of these examinations must be determined by the medical service, unless it is particularly specified by law for such employees, as those handling foods, and so on. Although many industrial physicians have abandoned the arbitrary method of making an annual examination, it is probably an ideal procedure and a good working rule for most medical services. It is true, however, that many of these periodic examinations may reveal no change of the physical condition of the workmen. For the employees who are exposed to specific hazards such as those of lead, benzol, silica, mercury, and T.N.T., monthly, bimonthly, or even weekly check-ups may be necessary. Employees holding particularly responsible positions, such as train operators, locomotive engineers, bus drivers and pilots, should likewise have more frequent examinations.

If the medical service is providing no treatment for non-industrial diseases, *a close cooperation should exist with the employee's family physician.* Without this cooperation, correction of defects is not likely to be given adequate consideration. If a family physician finds that the industrial physician is reporting to him regularly, he is much more likely to be willing to cooperate.

For periodic physical examinations the same standard for the classification of physical conditions is usually used as has been used for pre-employment appraisal. The application of these standards in most examinations is likely to be exactly

the same, except for a few disabilities which may develop during a man's employment. If these defects which develop during employment are of a character which would ordinarily bar him from employment or the particular position in which he works, most executives and medical services endeavor to find within the industry a place for such an employee, provided his previous records have been satisfactory. When, however, a disability develops which is dangerous for any type of employment, the examining physician should not hesitate to place this man in the unemployable category. Examinations for specific hazards being carried out as frequently as once weekly or once monthly rarely need to have a complete physical examination, but rather some special type of examination indicating undue exposure or the effects from such particular hazards. Some of these examinations for specific hazards may be best carried out by a plant physician when the man is actually on duty.

3. PHYSICAL EXAMINATIONS—POSTSICKNESS

One of the most important duties of an active industrial medical service is to re-examine all employees returning to duty following illness. This is important, not only to be certain that the employee has sufficiently recovered from the illness but also to be certain that this present illness has not caused critical defects which might alter his classification, or more important still, which should be under observation or treatment.

If an industrial medical department is sufficiently broad in its service to give diagnosis and treatment to nonindustrial diseases, the examination after illness is probably less important, but nevertheless should be carefully done. When an industry does not provide treatment or diagnosis for nonindustrial diseases, the examination after illness is much more imperative. Most attending physicians not attached to industrial medical services give careful adequate treatment for most diseases, particularly if the disease is acute and they are seeing the patients regularly. On the other hand, many chronic diseases are seen too infrequently by attending physicians and the constant tendency for the industrial employee

is to return to work and active labor too soon following illness. In some industries it is possible for a workman to be away from work for long periods and only see the attending physician on rare occasions and, in rare cases, not at all. Occasionally, also, some employees return to work with statements or certificates from attending physicians, which are given without very accurate knowledge of the cause of absenteeism or of the patient's actual physical condition, and certainly without a knowledge of the actual type of work which he is expected to assume and discharge as his duty.

Regardless of how competent an attending physician may be considered by the examiner, it is always a good policy in each case for the plant physician to make his own observations and form his own conclusions about the employee who is returning to work after illness. In arranging for examinations after illness, some scheme must be set up whereby all employees must report to the medical department after all absenteeism from illness or injury. For most industries, the choice of a specific arbitrary period of forty-eight hours is satisfactory. If the industry possesses an employees' mutual benefit association, or some group insurance scheme, it becomes much easier to keep a check on the absent employee who is ill. Time cards in use in industry may be taken from employees during illness. A certificate from the medical department for their release may insure re-examination before the employee returns to duty.

The *actual physical examination* of an employee returning to work after illness differs from pre-employment and routine examinations only in that the system which has been involved in the present illness should be given more careful consideration, as well as any complications which might arise from such an illness. *Routine chemical urinalysis* is especially important after most acute illnesses; and following certain types of disease, *chest x-ray* is particularly indicated. Many years of experience in examining workmen after illness show that the majority of men, after postsickness examinations, return to former duty without any alteration in classification. A relatively large percentage is required to take further treatment or to convalesce at home before being considered

fit to mingle with their fellow employees or undertake former duties. A small percentage is found to be sufficiently disabled by illness to require lower classification and an altered type of work. A still smaller percentage is found to be sufficiently disabled that further employment is considered inadvisable.

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WORKMEN'S COMPENSATION AND MEDICINE

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THE idea of Workmen's Compensation was introduced in the United States as a remedy for the unsatisfactory procedure of the Common Law suit as a means of recovery for loss of earnings and the cost of medical care because of occupational injuries. The principal of compensation is liability without fault, which eliminates the issue of negligence from consideration of occupational injuries.

The transition from the Common Law system and the issue of negligence to the Compensation system was not an easy one, since it required new legislation and, in many states of the country, a constitutional amendment before such legislation became possible. The complexities in framing Compensation Laws become apparent when one considers that administrative, legal, insurance, and medical aspects had to be apposed in order to develop a satisfactory law. However, during the period between 1911 and 1917, Workmen's Compensation Laws were enacted and became generally effective in the majority of our states. The purpose of this paper is to discuss the role that medicine has played in the development of the medical aspects of Compensation Laws and in their administration.†

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† Contributions to the subject have appeared in publications of the American Medical Association, American College of Surgeons, American Public Health Association, United States Department of Labor, in medical journals, and in textbooks. Perhaps the most comprehensive work in which this subject is discussed is the volume by Walter F. Dodd,[9] which is based on the data collected by the Legal Research Committee of the Commonwealth Fund of New York in their survey of the operation of Workmen's Compensation in the United States.

I. DEVELOPMENT OF WORKMEN'S COMPENSATION

The procedure in framing new laws when public opinion makes the need for them apparent was followed in the case of Workmen's Compensation Laws. Commissions were created either by legislative act or by the governor of a state to study the subject and make recommendations for legislative action.

There is a wide divergence of detail in the Compensation Acts of various states. Whether lack of uniformity is disadvantageous remains an open question about which there has been much discussion.[1a] There is, however, one point in common among the various state laws; namely, that money benefits be paid for earnings lost because of disability, and that the cost of medical care be allowed for *injuries arising out of, and in the course of, employment.* One significant variation exists in the injuries comprehended by the several laws. The statements about injuries to be covered vary as follows: "Accidental injury" or "injury by accident," "personal injury," "accidental personal injury," or the word "injury" alone. In all instances it is made explicit that the injury must arise out of, and in the course of, employment.

It appears that originally the types of injuries intended to be covered by Compensation Laws were those in which contact with physical or chemical agents and manifestations of injury were simultaneous, although disability may not have been coincident. In a large measure, such injuries are classified in medicine as traumatic, and the manner in which they are sustained may be referred to as accident. but to call them accidental injuries serves only the purpose of convenience in conversation, and is of no fundamental significance in medical thought.

The various terms written into the Compensation Laws were not defined therein, and they soon became the basis of controverted issues in disputed claims. Administrative decisions on these issues were appealed to courts for judicial decision. In general, these decisions conveyed the idea that "injury" must be a sudden and fortuitous event. In some jurisdictions the decision involved the idea of mischance resulting in "physical injury." Whatever the terminology contained

in judicial decisions, the requirement for tangible evidence was explicit with respect to the *manner*, *time*, and *place* the injury was sustained.

No attempt is made in medical science to define *injury* or *disease*. Both terms are employed to represent concepts just as do the terms *health*, *life*, and *death*. In scientific medicine, the approach to the study of disease, and the classification of disease, is through an understanding of etiology, the injury produced by etiological agents, and the manifestations of injury expressed as symptoms and physical signs—that is, the clinical picture. It is a matter of considerable importance to understand the relation of elapsed time between contact with etiological agents and the manifestations of disease, as in the matter of the incubation period in infectious diseases. In taking a clinical history, detailed information is sought regarding the circumstances of occupation; and quite frequently the data obtained reveal the etiology of the disease responsible for the complaints that led the patient to seek medical advice. Equally important, however, in determining the etiological factors concerned with the disease, are the inquiries about the home environment and the activities of a patient during hours away from work. Physicians are concerned with the *natural history of disease*, in which etiology is of first importance. Therefore, in considering circumstances of occupation in relation to disease, it is *occupational etiology*, rather than occupational disease, that is the object of inquiry.

Statutory provision or a construction of an existing statute was made to include disease which resulted from compensable injuries such as infection, paralysis, or epilepsy; but no provision was made to cover diseases whose etiology was directly concerned with the hazards of employment—that is, "occupational diseases." Compensation for these diseases in certain instances was allowed either through liberal judicial interpretations of existing statutes, or through judicial definitions for "occupational disease" which brought such diseases within the meaning of the law: that the contraction of disease was accidental.

The Legal-Medical Problem.—It is quite evident that the

approach to medical questions has been a legal one rather than a medical one, or a legal-medical one, with the idea of "accident" being the central thought around which the meaning of "injury" revolves. Only occasionally has there been evidence to indicate that attempts have been made to apply available scientific medical knowledge to the medical problems presented.

Perhaps the most interesting example of a compensable affliction illustrating the extreme discrepancy between medical opinion and legal interpretation is that of *hernia.* In those states where hernia is compensable, statutory provisions have been made which enumerate prerequisites which must have been fulfilled for a claim to be valid. Johnstone[2] states that in no comparable instance is medical opinion so ignored by administrative decisions in California as in the case of hernia. The present compensation status of hernia is well expressed by Harvey Stone:[3] "If a decision grants compensation to a workman for hernia, it does not follow that hernia was caused by the man's work but simply that under the provision of the law the man developing hernia while working is considered entitled to compensation. As a matter of fact, prevailing medical opinion is opposed to the view that the incidents of ordinary muscular effort have anything but minor contributory influence in the development of ordinary formation of hernia." Kessler[4] has summarized the various prerequisites stated in the laws which have statutory provisions covering hernia. In addition, he has made a splendid analysis of the medical, legislative, and legal interpretations of hernia in relation to accidental injury. Interestingly enough, in *none* of the Acts is hernia regarded as accidental injury, but as something that results from injury. Quite separate and apart from compensation considerations, many employers have a most generous attitude toward hernia and provide their employees with surgical relief and money benefits for time lost.

Compensation Today for Occupational Disease.—It has been stated above that no statutory provisions were made in the original Compensation Acts to cover diseases contracted by exposure to specific hazards of employment. An exception to this, however, is the case of Hawaii (1917). The

State of California was the first to amend its Act (1917); the amendment became effective in 1918. At the present time, twenty-five states and the District of Columbia have specific statutes providing compensation for "occupational diseases," and in addition there is the Federal Longshoremen and Harbor Workers' Act. In certain states the statute explicitly excludes diseases other than those which are complications or sequelae of an "accidental injury." In many of the states, special commissions were formed by legislative act or by executive order to study the question of occupational diseases in relation to their coverage by the Workmen's Compensation Act. In some instances these commissions have been aided in their work by the results of state surveys evaluating existing potential occupational hazards; Maryland[5] and Utah[6] are examples of states following such procedures. It is not within the scope of this paper to discuss further occupational disease legislation as such.[7] However, for our present purpose it is important to indicate the medical problems concerned in this field.

There are three *legislative methods* employed to provide compensation for "occupational diseases":

1. *The Schedule Method.* By this method the compensable diseases are enumerated and named with a description of the process wherein the disease must occur in order to be compensable.
2. *General Coverage Method.* This provides compensation for "any and all occupational diseases" without definition of the term "occupational disease."
3. *Definitive General Coverage.* This is general coverage with a Statutory Definition of the term "occupational disease."

No reason exists for supposing that a precise definition can be written for "occupational disease." Currently the merits of the three forms of coverage are being extensively debated. The whole question deserves, and should be given, thoughtful consideration by representatives of medical science, since the determination of fact regarding diagnosis and extent of disability is largely a medical problem and is accomplished in many instances only by experienced clinical study and judgment. It is important, in this connection, to point out the need for close cooperation with the industrial hygiene en-

approach to medical questions has been a legal one rather than a medical one, or a legal-medical one, with the idea of "accident" being the central thought around which the meaning of "injury" revolves. Only occasionally has there been evidence to indicate that attempts have been made to apply available scientific medical knowledge to the medical problems presented.

Perhaps the most interesting example of a compensable affliction illustrating the extreme discrepancy between medical opinion and legal interpretation is that of *hernia*. In those states where hernia is compensable, statutory provisions have been made which enumerate prerequisites which must have been fulfilled for a claim to be valid. Johnstone[2] states that in no comparable instance is medical opinion so ignored by administrative decisions in California as in the case of hernia. The present compensation status of hernia is well expressed by Harvey Stone:[3] "If a decision grants compensation to a workman for hernia, it does not follow that hernia was caused by the man's work but simply that under the provision of the law the man developing hernia while working is considered entitled to compensation. As a matter of fact, prevailing medical opinion is opposed to the view that the incidents of ordinary muscular effort have anything but minor contributory influence in the development of ordinary formation of hernia." Kessler[4] has summarized the various prerequisites stated in the laws which have statutory provisions covering hernia. In addition, he has made a splendid analysis of the medical, legislative, and legal interpretations of hernia in relation to accidental injury. Interestingly enough, in *none* of the Acts is hernia regarded as accidental injury, but as something that results from injury. Quite separate and apart from compensation considerations, many employers have a most generous attitude toward hernia and provide their employees with surgical relief and money benefits for time lost.

Compensation Today for Occupational Disease.—It has been stated above that no statutory provisions were made in the original Compensation Acts to cover diseases contracted by exposure to specific hazards of employment. An exception to this, however, is the case of Hawaii (1917). The

are usually medical, particularly in claims for alleged occupational diseases. Medical problems are concerned particularly with issues of *nature*, *extent*, and *duration* of disability, and in the case of occupational diseases, as previously stated. with the important questions of etiology and differential diagnosis.

Dodd[9] calls attention to the conclusions of a study of issues in 1073 contested compensation cases in Pennsylvania, of which 52.5 per cent were concerned exclusively with medical questions, 10.7 per cent involved both medical and non-medical questions, and 36.9 per cent were based on non-medical questions. He also quotes from the Governor's Committee on Workmen's Compensation in Ohio, 1934, that at least 80 per cent of the decisions of claims depend upon medical judgment. The higher percentage in Ohio is probably accounted for by the fact that fatal cases are excluded.

In addition to these considerations, it is true that a large portion of the compensation dollar is devoted to medical purposes. In the light of these facts, it appears that there should be a medical representative on the commission, or at least in the administration, serving in some prominent capacity. Physicians or surgeons have been appointed as medical advisers to the commissions, but the responsibility given to their positions has not been commensurate with the importance of the medical aspect of compensation administration.

It is in connection with *hearings on contested claims* that medicine is particularly inadequately represented. The procedure of hearings varies in detail in the different jurisdictions, but in general the legislative act states explicitly that hearings shall be as summary and simple as is consistent with ascertaining the substantial rights of the parties, and with justly carrying out the spirit of the law. The Common Law rules of evidence are dispensed with. Witnesses, of course, testify under oath and testimony is taken stenographically. In this respect the procedure is similar to trial courts, but it is obviously the intent of the law that hearings on compensation claims should be informal.

In discussing this subject, Downey[10] says that "Trial courts

gineer in this procedure, since the question of etiology is of first importance in determining the relation of a given disease to the hazards of a particular employment. The problems concerned with determining the facts of diagnosis and extent of disability for diseases allegedly contracted in the dusty occupations provide an illustrative example. Perhaps the most difficult problems arise in determining the relation between occupation and the diseases commonly observed in the general population irrespective of employment.

II. ADMINISTRATION OF COMPENSATION LAWS

In some of the states, the administration of Compensation Laws was placed in the *courts*, while in others a *commission* form of administration was established. Experience soon indicated that the commission type of administration was the better one, since the major portion of administrative functions falls in the category of business experience and at least 95 per cent of the claims filed are uncontested.

Tenure of Commissioners.—In many quarters the hope was entertained that membership on these commissions would offer opportunities for career men, since it was thought that permanence in tenure of office would be more likely to develop sustained effective administration.[8] It seems reasonable to assume that frequent changes in the administrative heads would be inimical to a continuing and efficient organization. In the Province of Ontario, Canada, where permanent tenure exists, the experience has been highly satisfactory, in contrast to the dissatisfaction frequently expressed in reports of special investigation committees in many of the jurisdictions in the United States. There were no statutory provisions governing the eligibility of appointees with reference to a background of educational or professional experience, or particular talents. *Medical representation* both on the commission and in the administrative organization has been inconspicuous.

Role of Medicine.—The importance of the medical side of compensation administration is realized when one considers that awards in the vast majority of claims rest upon medical data. In the case of contested claims, the controverted issues

comprehensive statistical information relevant to occupational accidents and diseases. The data available concerning *frequency, severity*, and *fatality rates* of accidents and diseases are wholly inadequate. Too frequently the available data are merely described rather than subjected to the analytical statistical treatment which is needed in planning programs in preventive medicine, formulating safety regulations, making insurance rates, framing legislation, and providing general information.

The International Association of Industrial Accident Boards and Commissions, whose membership is constituted of persons engaged in administering Compensation Laws, was organized in 1914 for the purpose of defining and discussing problems pertaining to administration. The need for improved statistical work and better medical service and supervision in the administration of Compensation Laws has been recognized by this Association, and recommendations have been made for improvements in these departments, but, as Dodd[9] says, "Unfortunately the official positions of the members of this Association and their uncertainty of tenure have kept the recommendations of the Association from receiving the attention they have merited."

In fairness to the commissions administering Workmen's Compensation Laws, it should be said that the budgets for operation are, in most instances, inadequate.

III. COMPENSATION INSURANCE

The most adequate Compensation Law will fail in its ultimate objective unless the benefits it seeks to bestow upon the disabled employee are guaranteed, and since 85 per cent of our American industrial plants employ less than 100 workers, it becomes obvious that security for payment of the benefits invokes the insurance principle.

Types.—There are several types of insurance covering the compensation field: *stock and mutual carriers, self-insurance*, and *state fund insurance*. A description of the distinguishing features, or a review of the opinions that have been expressed about the merits of these different types of insurance, is not pertinent to the present discussion. It may be said,

depend altogether upon the initiative of litigants. They do not go out to find out the facts nor can they exercise effective supervision over uncontested settlements between parties."* Compensation commissions, on the other hand, are supposed to act as *investigators*, not as legal referees, and their job continues until proper arrangements are made for ultimate settlements. Since in a large majority of instances the controverted issues are medical, it seems that it would be more appropriate to have as examiners medical men whose qualifications fit them to make necessary inquiries during the hearing in order that the testimony recorded be in keeping with the prevailing medical opinion of the day.

Value of Medical Testimony.—Much adverse criticism has been made of medical testimony. In fact, there seems to be little dispute that what is usually called expert medical testimony is not competent; therefore, it is of little probative value, the reason being that it is usually *individual-opinion* testimony rather than an expression of prevailing medical opinion concerning the subject under consideration. Hearings before medical men would eliminate a great deal of spurious testimony. Indeed, in some of the more recent occupational disease statutes, provision is made for a Medical Board to investigate and hold hearings on all medical issues raised in disputed compensation claims for alleged occupational diseases. These boards usually consist of three medical men whose eligibility for appointment is determined by statutes setting forth required professional qualifications. The work of these boards will be followed with great interest and the results attained by them may determine, in large measure, the justification for extending the idea of medical men holding hearings on all controverted medical issues, irrespective of the nature of the claim.

Statistical information, with which medicine is particularly concerned, is a much neglected phase of the administrative organization of the commissions. There is no other source of data so complete, and no other agency is in a better position to carry out statistical analyses of such data, and to compile

* Downey, E. H.: Workmen's Compensation, 1924. By permission of The Macmillan Company, publishers.

sion, as well as those of organized labor, believe that most of the abuses which have developed in insurance or compensation medical practice are attributable to the fact that the employee's physician is selected by a third party, and that a solution of the difficulties would be reached by allowing the employee to choose his own doctor. Whether this viewpoint is correct is open to question. The fact remains that there is apparently widespread commercialization in this practice, and that insurers may too frequently procure physicians at bargain-counter rates, or select one for his capability on the witness stand rather than for his professional qualifications. There is no sound basis for the contention that the average workman would be any the less the victim of unscrupulous medical practices, or that the best medical service would be obtained, if he had free choice of physician. The reasons for the unsatisfactory status of insurance-medical practice are to be sought elsewhere.

Importance of Proper Administration.—A viewpoint worth consideration has to do with the fundamental organization of casualty insurance, in which the operation revolves around the claim department. As previously stated, it is not so much the type of insurance organization but the quality of the supervision of its administration that is important in any insurance system. In presenting this thought, Downey[10] states four purposes of supervision, and Dodd[9] adds two additional ones. None of the six purposes includes supervision of medical service.

With some notable exceptions, the medical department of casualty insurance carriers has an extremely inconspicuous or inferior place in the organization. The procurement of physicians is left almost entirely to claim agents and adjusters. If the insurance companies were actuated by consideration of the quality of medical service in their choice of physicians, and if efficient supervision of insurance-medical practice were required, and the responsibility for these functions placed in a strong medical department, the probability is great that many of the medical abuses connected with compensation practice would disappear and the outcome would be financially profitable to the insurance business. The insurance com-

however, that most students of the subject believe that the social ends of Workmen's Compensation can be attained under any type of insurance organization, the important consideration being the quality and efficiency of administrative supervision in any particular insurance system.

Medical-Insurance Relationships.—Through insurance several hundred million dollars are disbursed annually in payment of awards by compensation authorities in the United States. Of this huge sum, a large portion is paid for medical, surgical, and hospital care. From an economic viewpoint alone, therefore, medical-insurance relations occupy an important place in compensation administration. Reports of numerous official investigations into the operation of Workmen's Compensation Laws afford convincing evidence of frequent gross and glaring abuses that reflect no credit to either party in this relationship. The blame is shared by both the practitioners of medicine and the insurance operators. No attempt is made to apportion the blame. This unfortunate situation may be accounted for by a number of reasons, some of which are tangible and others less so.

The impact of Workmen's Compensation Laws on medical practice caused radical changes in the traditional physician-patient relationship, since it introduced a tripartite relationship. It was entirely new to a physician to be called upon to treat the patient with a third party under obligation to assume payment for this service. Also, the private and confidential nature of the relationship between doctor and patient was abrogated, since the physician's recorded clinical observations and the clinical history of any given case became a part of the record of the claim for compensation; and in this sense compensation or insurance practice becomes a matter of *public* rather than private service. This changed order of medical procedure did not take into account the preference of the employee to be treated by a physician of his own selection. The insurer who paid the bill assumed that he should have some say in the selection of the physician to treat the insured workman.

The question of the *free choice of physician* has been a hotly debated subject. Some members of the medical profes-

sion, as well as those of organized labor, believe that most of the abuses which have developed in insurance or compensation medical practice are attributable to the fact that the employee's physician is selected by a third party, and that a solution of the difficulties would be reached by allowing the employee to choose his own doctor. Whether this viewpoint is correct is open to question. The fact remains that there is apparently widespread commercialization in this practice, and that insurers may too frequently procure physicians at bargain-counter rates, or select one for his capability on the witness stand rather than for his professional qualifications. There is no sound basis for the contention that the average workman would be any the less the victim of unscrupulous medical practices, or that the best medical service would be obtained, if he had free choice of physician. The reasons for the unsatisfactory status of insurance-medical practice are to be sought elsewhere.

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panies have been the victims of abuses by management and by members of both the legal and medical professions, working perhaps in collusion and often separately, and this offers a further reason for better medical supervision.

Dodd[9] suggests that all commercial clinics, insurance clinics, contract hospitals, hospital associations, or other organizations which are operated to treat occupational injuries and diseases for private profit should be abolished by law. They have not served any good educational purpose, and they have done little, if anything, for the cause of industrial medicine and hygiene. Kessler,[4] however, calls attention to the fact that there are some organizations engaged in contract practice in which a high standard of medical service is maintained. Nonetheless, reports indicate that abuses in such organizations, so far, have been much greater than any benefits.

Occupational Health Clinics.—Worthy of consideration is the advantage that would be gained in establishing occupational health clinics. At first, these clinics should be part of *university* medical centers and closely affiliated with the faculties of public health and hygiene in the universities. Provisions should be made for clinical investigation and the development of facilities for laboratory procedures in hygiene—similar to the development of facilities available in general hospitals of clinical laboratory procedures—in addition to facilities for diagnosis and treatment, physical examinations, and rehabilitation services. Subsequently these clinics could be organized in places isolated from the university, with some modification to fit the needs of a given community. In these clinics physicians would work under supervision and get training which would qualify them to work in the field of industrial health and medicine either for a career or for part-time practice. Students preparing themselves for public health work, especially in connection with bureaus of industrial hygiene, could obtain the clinical experience they need and do not get in the present educational organization. The clinic also would afford an opportunity to check and follow end-results of treatment—a phase of compensation work now so meagerly developed.

It may be said that the initial cost for such an undertaking

would be tremendous, but when educational value and potential saving are considered, this cost is more than justified. It might also be said that such a plan would interfere with private medical practice—I think it would not. I think it would give emphasis to a difference between private and compensation practice too infrequently recognized.

IV. CONTROL AND PREVENTION OF DISEASE

Prevention of occupational accidents and diseases is more important than compensation benefits, and rehabilitation is more important to a disabled worker than continued compensation payments. It is interesting, in this connection, to note that recently enacted Occupational Disease Laws have statutory provisions which make it the duty of State and City Health Departments to formulate rules and regulations for the control or prevention of occupational diseases, and which give them the power to enforce these regulations. Compensation Laws have been responsible, in part and indirectly, in bringing into existence, and developing, the professions of Safety Engineering and Occupational or Industrial Hygiene, and these groups, together with the Sanitary Engineering group, have performed outstanding service with gratifying results in eliminating or controlling many occupational hazards.

Health Programs.—Perhaps the most important indirect influence of Workmen's Compensation Laws has been the emphasis given to the need for continuing into adolescent and adult life those organized health programs which have resulted in striking achievements in childhood. Physical and mental examinations represent the foundation of these programs. The results of current examinations of draftees alone is an indication of *the urgent need for a large-scale system of physical examinations.* This subject has been discussed in terms of industrial examinations for pre-employment, periodic post-employment, and placement purposes, and much adverse criticism has been directed at the idea of such a procedure on the grounds that large numbers of unemployables will emerge. Such criticisms are entirely speculative, since there are no substantial facts to justify this point of view. The logical basis for considering the subject is that of a continuing health pro-

gram from childhood into adolescent and adult life. If the lessons taught by the results of current physical examinations of draftees are not sufficient, perhaps to these facts may be added the incidence of pulmonary tuberculosis in adolescent and adult age groups. When pulmonary tuberculosis is diagnosed in a large majority of persons during the second, third, and fourth decades of life, the disease is either moderately or far advanced. As a matter of fact, many large industrial and commercial concerns operate well-organized health programs now, with profit from both the health and economic-social points of view.

With the abundant evidence available to indicate the value of adult health programs, one might think there would be a demand from the general public for more extensive development along these lines of progress. While physical examinations represent the foundation of these programs, equally important are the problems of nutrition, and the activities during the period from the end of one work day to the beginning of the next, in developing and maintaining physical and mental fitness. The choice is whether it is preferable to deal with the reality of a large group of persons disabled on account of pulmonary tuberculosis, or nurture the none too certain idea of large numbers of "unemployables." A moment's consideration of the total number of gainfully employed individuals among the population of this country indicates clearly that occupational health is a field of interest and endeavor in which the most information is to be had, and in which the greatest achievements may be anticipated in maintaining adult health practices.

V. SUMMARY AND CONCLUSIONS

In conclusion, it may be said that the operation of Workmen's Compensation has been successful as a remedy, in most situations, for the Common Law suit as a means of recovering benefits for disability and the cost of medical care for occupational accidents and diseases. These laws have undergone considerable modification by amendment through the years, and there is still great need for further improvement.[11, 12, 13] Many of these amendments represent an effort to keep pace

with the judicial construction of the Acts, which on the whole has been liberal. The judicial decisions have dealt with construction of the word "injury," "accident," the phrase "arising out of and in the course of employment," and accidents or diseases which "accelerate pre-existing physical condition of an employee." It is suggested that for the judicial process there be developed, in some way, the means for including some thought about etiology in deliberations on the construction of the Acts.

The difficulties that lie immediately ahead in the successful administration of these laws are related, in great extent, to dealing with diseases of the general population which at times are thought to be associated with circumstances of employment. Much remains to be done in the field of evaluating disability in general, and particularly in the field of aggravation of pre-existing disease by accident and disease, and vice versa.

The following quotations from Dodd[9] sum up the situation very well: "The statutes have been enacted with a view to indemnity for injuries and diseases attributable to industry, and they have their actuarial basis established upon such a view. Irrespective of the merits of unemployment and health insurance, of insurance against old age, or of insurance covering all accidents to employees or others, Workmen's Compensation must be judged on the basis of its more limited purpose; and Workmen's Compensation as now understood will be weakened if an attempt is made to extend it to other fields of workmen's insurance without a concurrent reconstruction of its actuarial basis and of the governmental machinery for its administration." And in the final paragraph of his book, "The charge to industry of the cost of Workmen's Compensation should not be united with other types of social insurance. Workmen's Compensation should be an obligation of industry; other types of social insurance, if undertaken, should be an obligation of society, of which industry is but a part."

The Position of Medicine in a Workmen's Compensation Program.—Medicine has played an inconspicuous role in the development and in the administration of Workmen's Compensation Laws. The medical problems concerned with these

gram from childhood into adolescent and adult life. If the lessons taught by the results of current physical examinations of draftees are not sufficient, perhaps to these facts may be added the incidence of pulmonary tuberculosis in adolescent and adult age groups. When pulmonary tuberculosis is diagnosed in a large majority of persons during the second, third, and fourth decades of life, the disease is either moderately or far advanced. As a matter of fact, many large industrial and commercial concerns operate well-organized health programs now, with profit from both the health and economic-social points of view.

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Law, or an employer's Compensation Law, or an insurance company's Compensation Law."

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laws are an integral part of industrial-medical relations. If the present position of medical service in the compensation field is to be improved, action must be taken by educators to offer instruction in the special problems of industrial health and medicine. Management also must recognize the distinctive professional qualifications required of medical men for practice in the field of industrial health and medicine, and establish positions of importance commensurate with the requirements for special training, so that young men who are properly qualified in the fundamentals of clinical and preventive medicine will be attracted by the opportunities offered for a professional career.

Industrial health and medicine require, in addition to training in clinical and preventive medicine, study of the subject content of public health with special emphasis on occupational hygiene, biostatistics, and administration. The subject of administration is concerned particularly with the problems of public and labor relations, management, casualty insurance, and Workmen's Compensation Laws.

The content of medicolegal considerations in industrial medicine differs strikingly from those of conventional forensic medicine. It should also be emphasized that the activities in the field of industrial medicine are much more closely correlated with the engineering profession than is the case in usual clinical practice, and adjustment to this relationship is important.

The responsibilities for the future of medicine in connection with the operation of Workmen's Compensation rest, in no small measure, with organized medicine and upon its attitude and effort expressed through its national, state, and county medical societies. Lazenby[1b] has discussed these responsibilities together with suggestions for the proper consideration of them. He emphasizes the need for medical men to study compensation legislation in order to know that the demands made of medicine are practicable. He also expresses the important thought that "we must never lose sight of the party of prime interest, the *disabled worker*. This is a Workmen's Compensation Law. It is not a doctor's Compensation

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TUBERCULOSIS AS A COMPENSATION PROBLEM

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This discussion will be limited to pulmonary tuberculosis and its relationship to factors in the industrial environment, excluding trauma.

MEDICAL AND INDUSTRIAL HYGIENE ASPECTS

Pulmonary tuberculosis has long been known as one of the most widespread and costly of the endemic communicable diseases, particularly because of its chronic course. The disease attacks persons without regard to occupation and regardless of financial status, although there are differences in rates when race, age grouping, living standards, and geographical location are considered. Because pulmonary tuberculosis primarily affects the respiratory organs it has been erroneously assumed that many manufacturing materials and substances inhaled have a direct effect upon the disease, disregarding the importance of the specific etiological factor, tubercle bacilli; this has led to unwarranted conclusions. It will be the purpose of this paper to point out just what definite industrial relationships are now thought important by authorities, and to show how these relationships have or have not a distinct bearing on the medicolegal problems which follow the contraction of the disease.

Two kinds of adult pulmonary tuberculous infection are said to occur: the *endogenous* (which spreads from within by way of the blood stream or the bronchial pathways after the reactivation of a former focus) and the *exogenous* (which results from the entrance of tubercle bacilli from outside the body, through contact with other persons having the disease). Although some cases of the endogenous type are believed to

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thirty experienced observers reported on the incidence of tuberculosis in different industrial environments and discussed the effects of factors that have been alleged to favor the development of tuberculosis. (A full report of these proceedings is being published and distributed by the National Tuberculosis Association.) Some of the conclusions as pointed out by Dr. Leroy U. Gardner,[3] the Director of Saranac Laboratory, were as follows:

> It is clear that there cannot be tuberculosis without the tubercle bacillus —that the source of the bacilli is almost always individual. The most clinically significant is the reinfection type. There is a difference of opinon as to when infection occurs. There is a rising incidence of tuberculosis with advancing age, the bulk of which occurs in the group 15 to 30. There is one case per 2000 persons of new infections each year. Except for certain exceptions, *breakdowns* are not due to environmental factors. The standard of living is the main environmental factor. Of industrial exposures, free silica is the only one accepted without challenge. Of the dusts, only high free silica dust offers a change in the incidence of tuberculosis. Infection is not necessary to develop silicosis, but favors its development.

MEDICOLEGAL PHASES

Medical Problems

Occupational disease problems are now acknowledged by those having considerable experience, as being a great deal more complex than accidental injury problems in industry, although many adjudicating bodies are seemingly unaware of this. In other words, those who have to do with the trial or hearing of cases apparently believe that the same methods applying to accidental injury cases may be used in those cases involving or apparently involving occupational disease. There always remains the necessity in occupational disease cases, or alleged cases, of establishing definite causal relationships between *employment*, *disease*, and *consequent disability*. Likewise it is important to remember that the theory of the compensation laws is that a certain amount of money shall be paid to an employee because he has disability which prevents him from doing his usual work—the disability having arisen from a disease which he contracted because of certain peculiar circumstances in his occupation.

Industrial Hygiene Engineering Survey.—It is apparent

occur, the prevailing conception is that most adult tuberculosis is the result of contact infection.

According to Dr. Louis I. Dublin,[1] there has been a steady decline in the rates of tuberculosis mortality reported in the U. S. Registration Area, from 98.9 per 100,000 population about 1920 to 46.8 per 100,000 population in 1940. Mortality rates appear to rise early in adult life among white males and to continue this rise into the older age groups; however, tuberculosis remains responsible for more deaths between the ages of twenty and forty years than any other disease, and it is stated that approximately 16 per cent of all deaths between the ages of twenty-one and thirty-six years are attributable to tuberculosis. White females in contradistinction to white males, show a more rapid rise in rates between the ages of ten and twenty years and a gradual dropping off of the rates between twenty-five and forty-five years. Rates in the Negro population continue high as compared with whites, being three to four times that of the white race.

It is particularly important that those who have to do with diagnosis, treatment, and rehabilitation, accept a recognized classification of pulmonary tuberculosis. Details cannot be given here, but reference should be made to "Diagnostic Standards and Classification of Tuberculosis," 1940 edition, published by the National Tuberculosis Association.

The *cost* of tuberculosis has been variously approximated by different observers. Major General Charles R. Reynolds[2] has estimated the cost of tuberculosis for each man, taken into service with tuberculosis during World War I, or who developed the disease during or after his service, as between $7000 and $10,000, and that the total cost of tuberculosis among veterans is rapidly nearing the one billion dollar mark. Figures have been quoted as to the cost of tuberculosis among industrial employees, the most recent quotation being $4000 per person involved.

The *effect of the working environment*, as already indicated, has given rise to differences of opinion which have a medicolegal implication. For this reason, the Saranac Laboratory at Saranac Lake, New York, held a Symposium on Tuberculosis in Industry, in June, 1941, at which nearly

capable of communicating the disease—for example nurses and other attendants in tuberculosis sanatoria. An exception to this principle, which has been recognized in the legal provisions in some states, is where tuberculosis occurs as a superimposed complication of silicosis, contracted during employment; in such instances, however, it is necessary to show causal relationships with respect to employment and silicosis by the use of industrial hygiene engineering procedures, as previously indicated.

The *rating of disability*, *rehabilitation measures*, and *criteria for return to work* become matters of great importance in the adjudication of compensation cases, when and if causal relationships have been scientifically established in the determination of genuine industrial etiology. (It is obvious, but must be mentioned, that no person with active tuberculosis should be at work but should be taking bed treatment.) As stated by Dr. W. A. Sawyer,[4] who has had considerable experience with tuberculosis in an industry with diversified forms of employment:

> "The type of individual, the amount and length of infection, age, sex, race, former and present living conditions, length of treatment, rapidity and completeness of healing, are all factors to be weighed in determining disability and return to work. Perhaps most important is adjustment to life in general and to the experience of tuberculous infection in particular. So often, the ability to fit back into routine work is a measure of how well the individual imbibed the lessons taught during treatment. I have known individuals to fail to readjust to work because they lacked a certain balance and steadiness. They could not reduce their extracurricular activities sufficiently to protect their reserve energy."

Tuberculosis in Heavy Industry.—The experience[5] of a so-called "heavy industry" is also of interest. In this plant it is realized that criteria for permitting men to return to work after an absence due to pulmonary tuberculosis represent a problem which is closely tied up with *tuberculosis case finding*, a program which goes on continuously at that plant. Certain basic advantages result from the program, as follows: (1) Clinically active cases, needing immediate sanatorium care (many of them with open cavities), are discovered before the individuals are sick enough to have sought medical care of their own accord. (2) Most discovered cases are either

that to establish etiological relationships between occupation, disease, and disability, it is necessary to make a scientific assessment of the factors in the working environment which may contribute to the etiological relationships. In specific terms, this usually involves an industrial hygiene engineering survey in which, by instruments of precision and laboratory methods, one can determine the nature of the exposure, both in quantity and quality, and then decide whether the exposure is really a hazardous one, capable of producing disease—by making comparisons with accepted standards. There are no other definite means of securing this information.

Applying this principle to the problem of tuberculosis among industrial employees, this means that an industrial hygiene engineering study must be made, particularly of the dust in the working environment of the employee, taking into consideration as required items of information the amount of dust generated during various operations, the particle size of the dust, the free silica content of the dust, and the period of exposure to these factors.

Merely because an employee has been exposed to free silica dust does not justify the conclusion that there was a hazard present in his former occupation. Medical examiners have constantly placed unwarranted confidence in the statements made by patients that they worked in a dusty atmosphere, and have proceeded at once to etiological and diagnostic conclusions, based merely on speculation and surmise.

Experience with the incidence of tuberculosis in industrial groups has definitely proved that only where large amounts of high free silica dust are inhaled over a period of years is that incidence unfavorably affected. Other air contaminants and physical conditions of atmosphere, such as gases, vapors, fumes, high and low temperatures, humidity, have not been found to exert an unfavorable effect on the tuberculosis morbidity rate.

Pulmonary Tuberculosis as an Occupational Disease.—Pulmonary tuberculosis *per se* cannot be considered an occupational disease within the meaning of the word "occupational," except in those instances when during the regular duties of the employee he or she comes into contact with other persons

Legal Problems

It is important to keep in mind that although there has been a definite trend toward the inclusion of occupational diseases in state compensation laws, *more than half of the states* have not yet placed such disabilities under compensation coverage, except as they may be complications of accidental injuries. This statement is of tremendous significance in the consideration of tuberculosis as a compensation problem, because it means that in more than half the states resort must be made for remedy for alleged occupational diseases to the common law courts, thus increasing the cost and length of litigation.

Some state supreme courts have rendered decisions to the effect that tuberculosis is not an occupational disease. In other jurisdictions, there has been such a variety of opinions that the material seems to represent a maze of judicial contradictions.

It is upon this background of legal and legislative uncertainty that Mr. Henry D. Sayer[6] has proposed (the suggestion being an individual one and not of any group or organization) that tuberculosis might be treated directly as an occupational disease under the law, not by broad general terms, but by very specific and definite provisions. *Not every case of tuberculosis occurring in a worker should be compensated and none should be without a just basis of liability of the employment.* Mere fanciful aggravations and activations of a pre-existent lesion should not be permitted to impose a liability upon the employer. Nor should sympathetic considerations and social needs be permitted to take the place of facts establishing fairly the liability of the employer. The questions would be so involved that determinations made by laymen, although they might be ever so sincere, would lead certainly to strange results in some instances. A board of expert medical examiners should be used to determine medical issues involved in a claim. It is realized that some sort of gradual approach to liability, such as was done in New York and some other states with reference to the silicosis problem, should be planned and that there will be many details which will necessarily have to be settled. The plan calls for the

inactive or only questionably active. These are usually permitted to continue working, and are kept under supervision, including periodic chest x-ray films. In the event it is decided that the employee is to leave work to take treatment, there has been built up a file of data from which it is relatively easy to estimate changes in the disease process. (3) Some knowledge has been gained as to the influence of various types of heavy industry employment on the course of the disease.

Return to work in the above plant after an absence due to pulmonary tuberculosis is based on evidence of inactivity: (1) in x-ray films, the lesions must be apparently inactive and have shown no change in recent serial films; (2) the sedimentation rate must be normal; the Weltmann test has been used as a hematological adjunct in a few cases—in a limited experience it has proved reliable; (3) physical findings must indicate inactivity of the lesions; and (4) sputum must be negative—this finding has little value because direct smear examination is the only procedure available to this group.

It was also found from the heavy industry experience that the *type of work* to which patients return is probably a matter of some importance. Deference is paid to the accepted view that hard work should not be engaged in for some time at least. Studies of inactive cases under observation have shown that the dry hot environment is of itself not harmful. Work in the open, without protection from the weather, has however proved to have an unfavorable influence on the course of the disease. These established environmental influences are given full consideration in the return to work placement. Individuals are x-rayed at specifically determined intervals. Those who did hard physical work before they "broke down" are, in some instances, permitted to return to their former jobs after prolonged observation, provided that the jobs are not located in the open. *Supervisory examinations*, including single films of the chest and sedimentation rates, as minimum procedures, continue to be made at intervals specifically determined for each case.

Waters especially with reference to claims for tuberculosis as a disease, in which the industrial environment [other than trauma] has been alleged to be the cause of tuberculosis or to be an incidental factor.)

3. In view of the fact that in certain instances tuberculosis has been held to be compensable, either as an occupational disease or as an accidental injury, and the further fact that employers may be faced with common law litigation involving claims for tuberculosis injuries, it may be well for industry to give cautious consideration to the possible compensation of such injuries as if tuberculosis were a compensable occupational disease. Legislation providing compensation for tuberculosis will probably present more perplexing problems than that for any of the diseases now considered occupational and, if such legislation is to be enacted, it should be surrounded by safeguards that will accomplish the following purposes:

A. To require a minimum period of employment under the employer sought to be held liable.

B. To relieve employers from liability for tuberculosis existing in employees prior to the enactment of the proposed law.

C. To establish the amount of compensation payable at a figure less than that provided for other diseases now considered occupational.

D. To provide competent medical examiners for the determination of the disease, its causation, and the evaluation of disability.

E. To relieve the employer from the cost of hospitalization and medical treatment by having the State provide such care.

It was acknowledged by Mr. Waters that the subject is broad, intricate. and perplexing, that it is of concern to every employer because of the potential cost to be imposed upon him for compensation for disability from tuberculosis. It was construed to be a further step in the direction of *health insurance* and it was believed that industry is not prepared at present to assume this additional burden. The problem is also of concern to every employee because it may lead to the denial of employment to workers on account of the potential expense of compensation to be awarded. Considering the difficulties under the administration of present occupational disease laws and repeated instances of the inability of older employees to procure employment because of the potential cost of compensation under such statutes; it was believed that if legislation were adopted to provide compensation for tuberculosis disability, it would be inevitable that industry might refuse to employ men or women who have evidence of healed or arrested pulmonary infection.

cooperation of all parties in industry, the best thought of the medical profession, the best skill of the engineering profession, and the help of public authorities and legislatures. Mr. Sayer stated that he was mindful of the imperfections of the suggestions made, but it was hoped that they would represent a contribution toward the solution of the problem of tuberculosis in industry.

In an unpublished paper entitled "Trends Toward Compensation for Tuberculosis as an Industrial Disease," read before the Sixth Annual Meeting of the Industrial Hygiene Foundation of America, at Pittsburgh, November 12-13, 1941, Mr. Theodore C. Waters[7] similarly discussed existing legislation and supreme court decisions. He stated that in none of the states in the United States that provide compensation by the schedule method is tuberculosis, *per se*, compensable. In those states it has been held to be compensable only when it follows or is superimposed upon some other compensable injury or disease, as for example, when silicosis becomes complicated by tuberculosis. In all other states, the question as to whether or not tuberculosis is compensable under the statute is subject to administrative or judicial interpretation. After commenting upon legislation and supreme court decisions, Mr. Waters summarized his conclusions as follows:

1. Tuberculosis is not an occupational disease within the legal definitions of that term that have been incorporated into our statutes and announced by judicial decisions. There should be no qualification of this conclusion except as to those cases where tuberculosis is superimposed upon a traumatic injury or other compensable disease or in cases where nurses or attendants of tuberculous patients contract the disease.

2. In those states where courts have affirmed awards of compensation for tuberculosis as an accidental injury, the courts seem to be too willing to accept the findings of fact by industrial commissions without analyzing the testimony, and bind themselves by the commissions' findings where such findings are contrary to the weight of the evidence. They have affirmed awards where the evidence on behalf of the claimant has been of the flimsiest character, relying upon the rule of law to the effect that any evidence, no matter how little or how weak, tending to prove the causal relation between the alleged accident and the incidence of disease, is legally sufficient to support an award. In cases of this character, most of the evidence as to the causal relation is highly speculative. These decisions represent an effort at liberal construction of a given law that fails to give effect to legislative intent. (The author can add similar experience to that of Mr.

tience, time and money, especially when compared with other diseases common to the general population.

Present and Future Factors Affecting Incidence.—In spite of the tremendous decline in the tuberculosis death rate in the registration area of the United States during the past twenty years, it must be kept in mind that the disease is now responsible for more deaths between the ages of twenty and forty years (the so-called industrial age) than any other disease, and furthermore, that about 16 per cent of all deaths between the ages of twenty-one and thirty-six years are due to tuberculosis. As pointed out by the Institute of Life Insurance, business booms bring a rise in the death rate (this meaning a general death rate) while a depression lowers the death rate. The theory is that with money plentiful people live faster and more dangerously, and this applies particularly to wage earners. It is reasonable to believe therefore that the tuberculosis rate among wage earners will rise during a boom, not because more money is being earned, but because there are more of what Dr. W. A. Sawyer calls "extra-curricular activities" which tend to lower the normal powers of resistance and therefore increase the chances of the contraction of the disease. Moreover, it is well known that during a postwar depression the incidence of tuberculosis rises and it can be expected, therefore, that the lowered standard of living through increased unemployment, will contribute unfavorably toward the morbidity and mortality rates of pulmonary tuberculosis. (There are already signs of the effects of war conditions on tuberculosis.[9] A survey made by G. J. Drolet, assistant director of the New York Tuberculosis and Health Association, has shown a rise of mortality in nineteen of forty-six large cities, during the period January 1 to November 15, 1941—although the general rate for the entire nation was lower. The upward trend in metropolitan areas was attributed to war conditions and lengthened hours of work in defense industries.)

SUMMARY

1. It is reasonable to expect an increase in the morbidity and mortality rates of pulmonary tuberculosis and, therefore,

DISCUSSION

The whole problem of tuberculosis in industrial employees is one of economics, and involves *case finding*, *treatment*, and *rehabilitation*. At the present time, it is estimated that a case of tuberculosis in an industrial employee costs somebody $4000.

The money used for treatment and rehabilitation procedures is a function of the time involved and is directly proportional to the chronicity of the disease. It must be understood that this is variable to a certain degree in different individuals.

If the experience of a ten-year period of service at the Potts Memorial Hospital, Livingston, N. Y. can be considered typical, there are some interesting figures for our consideration.[8] In a group of 246 tuberculous patients, the following data on *work capacity at discharge*, according to length of stay, have been set forth in the report: Of those who were patients for four months and less than six, 13 per cent were discharged either "apparently fully rehabilitated" or "probably fully rehabilitated;" those staying six months and less than nine—15 per cent; nine months and less than twelve—16 per cent; twelve months and less than fifteen—11 per cent; fifteen months and less than eighteen—11 per cent; eighteen months and less than twenty-four—11 per cent; and twenty-four months, but less than thirty—8 per cent. The report further shows that 85 per cent of the patients were discharged from the sanatorium in less than thirty months. Of the 85 per cent, approximately 42 per cent had been "apparently" or "probably fully rehabilitated," and 43 per cent were "partially" or "not rehabilitated." At the end of the first five-year period and at the end of the second five-year period, respectively, the following figures obtained: 70 per cent and 85 per cent were well and working; 12 per cent and 9 per cent were curing; and 18 per cent and 6 per cent were dead.

It is thus evident that in a well regulated institution, where organized and systematic attempts are made at early work tolerance under well directed supervision, the problem of restitution of tuberculous patients to society as self-sustaining individuals is one involving expenditure of considerable pa-

7. Professional testimony in compensation cases needs considerable clarification, especially with regard to proper qualifications of physicians giving testimony, and guidance by official medical agencies, as illustrated by the Minnesota experiment. It seems rational that organized medicine must itself undertake to do this job.

8. Professional qualifications for the personnel of quasi-judicial bodies, such as industrial commissions and special medical boards, must of necessity be raised and specific requirements met, if the complicated medicolegal problems of occupational diseases and alleged occupational diseases are to be equitably handled.

9. The economics of tuberculosis among industrial employees presents a tremendous problem in financial underwriting. Industry can by no means attempt to carry any greater burden than to defray the costs of case finding; the costs of treatment, rehabilitation and vocational education must be left to private agencies or to official public agencies.

10. If legislation is to be passed providing that tuberculosis disability among industrial employees shall become compensable, the provisions in the foregoing paragraph should be included together with other safeguards, as proposed by Mr. Sayer and Mr. Waters, and cited in this paper. Otherwise, the financial burden on industry will be so great comparatively, that the difficulties arising from silicosis during the past ten years will be as a drop in the bucket.

11. Finally, this subject needs great clarification and study. It is respectfully recommended that serious thought be given to the consideration of the appointment of national and state Commissions for the Study of Tuberculosis in Industry as a means of supplying adequate information for medicolegal guidance.

(AUTHOR'S NOTE: The limited length of this paper has made it necessary to exclude important case decisions, and legislation and other material. It is planned to include this and other discussion in a proposed expansion to monograph or book size.)

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an increase in the number of claims among industrial employees.

2. Pulmonary tuberculosis cannot *per se* be considered an industrial or occupational disease, except among employees who have personal contact with tuberculous patients, such as in hospitals and sanatoria; in industries where there is a great deal of high free silica dust generated, and where such an exposure over a long period of time is an incidental factor in unfavorably influencing the tuberculosis morbidity. It should be kept in mind that free silica dust is not the direct cause of tuberculosis—that relationship is limited entirely to the tubercle bacillus.

3. Where claims are filed against employers for tuberculosis in industrial employees, careful investigations must be made of the working environment, by means of industrial hygiene engineering studies, through which data may be secured as to whether high free silica dust exists in sufficient quantities and over a sufficient period of time to be appraised as an indirect factor in unfavorably influencing tuberculosis morbidity. In instances where direct contact is alleged with tuberculous patients, epidemiological studies should be instituted. There are no other scientific means for evaluating the etiology in the occupational environments for these types of exposure.

4. Physicians generally are not accustomed to inquiring into the engineering aspects and the epidemiological phases of occupational environments before presenting testimony in tuberculosis claim cases. Advantage should be taken of the services of official public health agencies and consultants in this respect, so that physicians may have at least some knowledge and appreciation of the application of this type of information.

5. Diagnostic standards of the National Tuberculosis Association should be followed with reference to the diagnosis and classification of tuberculous patients.

6. The rating of disability and criteria for return to work should be put upon a practical basis, similar to the examples given in this paper, with adaptation wherever needed, to the specific problems involved.

The Medical Clinics of North America
July, 1942.

NUTRITION IN INDUSTRY

WILLIAM A. SAWYER, M.D.*

THE nutrition of workers in industry is a relatively new phase of industrial medicine. As the preventive aspect of industrial medicine has become more generally recognized, the value of proper nutrition has been given more attention. The fact that diet inadequacies do affect the worker's efficiency, absence record, injury record, as well as his general physical and mental well-being is beginning to be accepted by the most discerning of industrial leaders. They realize that if workers are to keep well and turn out a maximum of production proper nourishment is necessary.

Have industrial workers been living on diets below the level considered adequate by leading nutrition authorities? This is a question which should seriously concern every one interested or in any way involved in the welfare of workers. Little information is available as regards the diets of workers themselves as distinct from their families. Surveys have been made in some parts of the country which seem to indicate that in a large percentage of cases workers and their families have been eating diets considerably below what they should be.

Stiebling in reporting on the diets of employed workers' families in different regions found that 26 per cent were poor, 45 per cent fair, and only 26 per cent good, as defined by Sherman. Among these families of employed workers, poor diets were least common in the Pacific Coast cities (approximately 12 per cent), less common in North Atlantic cities (approximately 20 per cent), and most common in the South (40 per cent in whites and 70 per cent in Negroes). The percentage of poor diets would be even greater if measured by the allowances specified as necessary by the National Re-

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Breakfast is apparently inadequate in quantity and quality and is often omitted entirely. Luncheon is inadequate in quality and often in quantity. Dinner is adequate in approximately 90 per cent of the cases.

During the summer of 1941 Dr. Robert S. Goodhart, on behalf on the Committee on Nutrition in Industry of the National Research Council, visited thirty-three large industrial concerns. He found in a casual survey that the majority of workers chose poorly-balanced meals, even when a good choice was available. Milk with meals was taken in only 10 to 25 per cent of those observed. In a large plant on the West Coast. Dr. Goodhart found that the sales of milk and orange juice ran a very poor second to that of soft drinks. It was a custom to send rolling carts through the plant in mid-morning and mid-afternoon. The largest sales were of candies and soft drinks. Around many of the plants of mushroom growth during the past two years, low grade, inadequate restaurants, and stands have sprung up. Their menus are not only limited as to variety but often sadly lacking in quality. Dr. Goodhart relates that in a West Coast plant with 5000 day shift workers, many arrived without their breakfast. Some came 30 to 40 miles to work each morning, reaching the plant at 7 A.M. The manager of the lunch concession serves over 1000 breakfasts daily of doughnuts and coffee. A similar situation was found in a large foundry near the Atlantic seaboard where the favorite breakfast was Danish pastry and coffee. In his report. Dr. Goodhart observes, "It is not unreasonable to suppose that such conditions must have adverse effects upon the nutritional status and health of the American worker."[1] Certainly we cannot expect to build solidly on such a dietary.

It is regrettable that more carefully recorded surveys are not available. If anyone wishes to find out what the situation is in his own plant, a check on trays or selections can be made easily. Meals should be classified as good or *adequate* if they include the following:

1. Meat, fish, cheese or egg dish (served as a hot food or in a sandwich made of whole grain or vitamin enriched bread)
2. Vegetable (hot or cold) or fruit
3. Milk, milk soup, cheese, creamed dish, or custard

search Council's Food and Nutrition Board. Sherman's standards are lower in almost all respects.[1]

NUTRITION AND DEFENSE

The question which should concern us more particularly just now is what kind of meals are workers in our war industries receiving. To be sure, we should always be concerned with right food for workers, but in this world-wide life and death struggle better nourishment is of paramount importance. Doctors and dietitians pale at the sight of defense workers eating a hamburger and a bottle of "pop" for lunch, or of workers rushing off to duty in the morning without any breakfast. Neither men nor women can do good work without breakfast or with an inadequate lunch.

There are always workers who are considered lazy or slow to make adjustments. The trouble may be not with their minds or their ambition, but with their stomachs! What they need is good food—food that will "fill the corners" and nourish the nerves, the blood stream, the skin, the teeth, and the brain.

If 45 per cent of the defense projects were found to be defective, public indignation would run high. And yet 45 per cent of our young men who were examined for the army were found to be below par physically,[2] and poor diet is doubtless responsible for a large percentage of this. Is not *man* power just as important as *machine* power?

THE WORKER'S DIET

Prevalence of Inadequate Diets.—Those of us who have observed what the worker eats in plant lunch rooms and in the home are immediately impressed by the inadequacy of selections.

We are concerned particularly with the *noon meal,* as that is the one eaten in the plant dining rooms. These meals can be divided roughly into three groups:

1. Lunches purchased in dining room.
2. Lunches brought from home and supplemented with a hot dish, a glass of milk, a dessert, or all three of these.
3. Lunches brought from home (usually a sandwich, cake or cookies and occasionally fruit) and not supplemented, or supplemented with only coffee or a soft drink or candy.

icians and Surgeons* has sent the following questionnaire to its twelve hundred members:

DIETARY QUESTIONNAIRE

I. What is approximate number of employees in your organization?

Day shift............Evening shift............Night shift............

II. *Supplemental Feeding:*

1. Does management provide any supplemental feeding between usual

meal times?............What is provided?......................

At what time(s) provided?......................................

How dispensed? Lunch carts, lunch counters, vending machines (underline).

2. Are vitamin concentrates given to employees?..............If so,

what vitamins?..

III. *Eating Facilities:*

1. What eating facilities are available for employees?

(*a*) Cafeterias or restaurants
(*b*) Rolling kitchens
(*c*) Lunch stands: Hot foods
Cold foods only (except coffee)
(*d*) Vending machines: (underline foods available) sandwiches, milk, fruit, cake, pie, other

Are there any separate facilities for executives or supervisors?......

2. Are the facilities operated by the management or by a concession? (underline)

If a concession, do employee organizations benefit by any profits?...

If management operated, is the management satisfied to "break even"?..............

What expenses other than food are charged to the cafeteria? (underline) Rent, salaries, light, fuel, equipment, insurance, maintenance

3. What proportion of the employees use the plant cafeteria or lunch service?................

* Committee on Nutrition of the American Association of Industrial Physicians and Surgeons: W. A. Sawyer, Chairman, H. S. Murat, A. G. Kammer, H. H. Fellows, F. G. Pedley, F. G. Barr.

The lunch is *inadequate* if lacking any one of the above. Such a survey will probably give some startling data; it is valuable if an effort is to be made to reorganize scientifically a plant food service.

Results with the Oslo Cold Diet in England.—In England, because of nutritional inadequacies among workers and the necessity of keeping up health by a well-balanced ration, nutrition experts are attempting to give in the six days of work one meal each working day or period containing at least two-thirds of the daily vitamin and mineral needs. It is now a law in England that in all plants of over 250 employees facilities must be provided to give one good meal each day. In most instances the workers pay for this. The cost averages approximately 25 cents. Where the Oslo Cold Meal has been used, it has met with general acceptance. This consists of milk, whole wheat bread or biscuits, butter and raw fruit or vegetables—the so-called protective foods. This meal, of course, has the advantage of requiring no cooking or preparation.

"In the October 1940 issue of the *Journal of the Royal Institute of Public Health and Hygiene* (vol. 3, p. 253), Margaret D. Wright describes an experiment in substituting the Oslo meal for the hot meal previously served, in a small industrial canteen in Great Britain. Her report is of particular interest because, throughout the period of study, the employees were permitted a free choice between the Oslo meal and their usual lunch, either meal being obtainable at the same price. The daily variation in the number of lunches of the Oslo type consumed, during the month of study, ranged from 61 to 85 per cent of the total lunches, the lowest weekly average (71 per cent) being obtained for the second week of the experiment.

"Her work demonstrates the practicability of attempting to change the dietary habits of workers by attacking simultaneously along the lines of education, economy and provision.

"Miss Wright makes the interesting observation that 'The educational value of the meal must be considerable, as the workers here will certainly discuss it in their homes. The practical example of having the protective foods presented daily in attractive combinations will do more to inculcate the knowledge of which foods are important for health than any other appeal which could be devised for a community so diverse in occupation, interests, and general background.' "[1]

Dietary Questionnaire.—In order to have more facts regarding how workers are fed in the plants, the Committee on Nutrition of the American Association of Industrial Phys-

tional deficiencies, such as very mild interstitial keratitis, characteristic of early riboflavin deficiency.

Williams, Wilder, and their associates[5] have shown some very interesting results in adults maintained on a *thiamine (vitamin B_1) deficiency* for three months. Fatigue, lassitude, and loss of appetite developed early and increased progressively. The more active the person, the sooner did severe symptoms develop. Other symptoms observed were depressed mental states, generalized weakness, dizziness, backache, soreness of muscles, dyspnea, insomnia, anorexia, nausea, vomiting, loss of weight, roughness of the skin, and flabbiness of the muscle. Capacity for muscular work fell progressively and there were indications of weakened heart action. Restoration to the diet of adequate amounts of thiamine sooner or later brought an end to these signs and symptoms.

These investigators have further shown that a diet sufficiently rich in thiamine to prevent the development of obvious deficiency disease is not necessarily adequate for the best nutritional state, for larger amounts increased the alertness and attentiveness of experimental subjects and led to increased working capacity.

Since leading authorities in nutrition have expressed the view that thiamine deficiency is probably one of the most common dietary deficiencies in this country, it should be obvious to any physician engaged in supervising the health of workers that there is nothing more necessary and urgent than an effort to improve the dietary of workers, thereby preventing such signs and symptoms as outlined above.

Poor diets are apt to be deficient in more than one essential. Persons who suffer from pellagra because of a deficiency of niacin (nicotinic acid) are apt to show signs of deficiency in thiamine and riboflavin as well. A diet comparatively low in several essentials may produce a condition which may be and often is mistaken for neurasthenia. In these cases there is a rapid return to good health when the individual is put on a diet rich in all the essentials.

Nutritional Conditioning.—With such deficiencies as have been mentioned above, one cannot help speculating as to the results of feeding adequately a group of at least a thousand

4. How much is the average meal check?...............

5. Do you employ a trained dietitian as manager of your restaurant facilities?...........

   If not, what qualifications does the manager have?...............

   ....

6. Does the plant physician have any jurisdiction over or any connection with the cafeteria service?......To what extent?.........

7. Are combination plate lunches served?........If so, at what price? ....To what extent purchased?.........Which of the following do they include? (underline)

Soup	Potato or substitute	Salad	Bread and butter
Meat or substitute	Vegetable	Beverage	Dessert or fruit

8. Has any study been made of food selections?.................

   Name of organization...............................

SPECIFIC DEFICIENCIES

Recognizable nutritional diseases exist in many parts of the country. *Beriberi* has been found in some of our eastern seaboard hospital clinics and in Western New York and Ohio. In addition to neuritis, cêrtain cardiovascular manifestations of the disease have been observed frequently.

Pellagra prevails widely in the South where *nutritional edema* is also found in some 15 per cent of hospital patients. *Nutritional anemia* is common. *Scurvy*, *rickets*, and other specific deficiency diseases may be found occasionally throughout the country. While we would not expect to find among industrial workers generally many clear-cut cases of these easily recognizable deficiency diseases, nevertheless with the poor diet selections observed in our plant restaurants, it is reasonable to assume that there are numerous borderline deficiencies. There is a wide range between the mildest forms of malnutrition and the frank easily diagnosable case. Research is revealing the earliest signs and symptoms of nutri-

tional deficiencies, such as very mild interstitial keratitis, characteristic of early riboflavin deficiency.

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Nutritional Conditioning.—With such deficiencies as have been mentioned above, one cannot help speculating as to the results of feeding adequately a group of at least a thousand

workers over a period of one year, keeping very careful records of all factors involved, and having a control group for comparison. It seems reasonable to suppose, in view of certain research that has been done, that many of these individuals would be greatly improved in health and endurance. This would be a worthwhile effort in preventive medicine.

"Some work carried on by the British Army in recent years demonstrates the improvement in health and physique which follows what might be called 'nutritional conditioning.'

"The army authorities were alarmed at the large percentage of would-be recruits who were rejected on examination. This was 52 per cent in 1934 (56 per cent for the air force) and 43.4 per cent in 1935. A Physical Development Depot was established at Canterbury to deal with would-be recruits who had been rejected mainly for underweight and deficient chest measurement. (It had been found that men who were underweight when joining the forces were more likely to be invalided out than overweight men. It had also been determined that capacity to endure severe physical stress was found most commonly in overweight men.)

"Measures for effecting improvement in the health of the unsuccessful recruits included: (1) optimum diet; (2) long sound sleep; (3) hard physical work; (4) healthy recreation. Milk and fruit were added to the presumably adequate army ration. In addition to four regular meals, a snack was served at 10:30 A.M. (milk or soup and fruit), and the men had tea (tea, biscuits and barley sugar) in the afternoon.

"As a result of this conditioning, 87 per cent of 834 young men so treated were accepted and passed into the army. Only 5 per cent were afterwards discharged on grounds of medical defect."[1]

Present Studies of Diet and Nutritional Condition of Workers.—It must be evident to anyone who has studied the situation carefully, so far as promoting the health and efficiency of war workers is concerned, that the greatest present need is more facts. With that in mind, the Committee on Nutrition in Industry of the National Research Council is organizing and sponsoring carefully controlled studies of the diet and nutritional condition of workers in several places in this country. One of these began in November of 1941 and plans for a second study are well advanced. In these studies a certain number of workers will be thoroughly examined, including a detailed food habit history, with special consideration of signs of nutritional deficiencies. Nourishment will be given to some of this group in the form of natural foods and to others as synthetic vitamin supplements and minerals. Careful records of illness, absence from work, accidents, produc-

tion efficiency, and so on, will be kept and comparisons made with a control group. In this way, it will be possible to draw some valuable conclusions as to the importance of overcoming nutritional deficiencies.

The medical examinations conducted in these studies include such factors as a biomicroscopic examination of the eyes, determination of blood ascorbic acid, hemoglobin, red cell count, cell volume, serum albumin, and changes attributed to vitamin A, thiamine, riboflavin, niacin (nicotinic acid), and vitamin C deficiencies. Gastro-intestinal complaints are carefully recorded, as well as all other significant factors in the medical and dietary history. Such data together with other facts as mentioned above should make a very complete and convincing study. Similar worthwhile tests can be made in any plant without delving into as much detail. We need more surveys. It is hoped that many physicians in industrial medicine will become sufficiently interested to carry on bits of research with adequate controls, thus making more convincing the real values of nutrition for workers.

VITAMIN SUPPLEMENTS

It is understandable why nutritionists recommend that individuals get their vitamins and minerals in their food. That is obviously desirable. However, on the basis of accumulating evidence, there are many who do not eat the right foods, even when they have the opportunity. I am convinced that the average individual does not obtain an adequate amount of vitamins and minerals in his daily diet. Furthermore, I wonder if anyone with an ordinary appetite or capacity for these protective foods can eat enough of them to get all the vitamins required to maintain good health.

It is true that, with a good diet, vitamin supplementation should not be necessary. But in industry we do not have much control over the employees' diet except at the noon meal and there are countless numbers who bring their own food from home or buy a sandwich and a soft drink or cup of coffee. They may have a fairly good breakfast and a good dinner, but these two meals cannot make up for the inadequacies of the noon meal. For this reason in our Medical

Department we advocate vitamin therapy to all employees who are subject to upper respiratory infections, under and overweight, and those working overtime under undue physical and nervous strain. It has been interesting to note that they report less fatigue, more "pep," and increased energy as well as better appetite after taking the vitamins. It may be a "shot-gun" type of supplementation, but until we know how to test easily and accurately for different vitamin deficiencies, and in view of present urgent needs for better health, it seems safe and wise to give as supplements at least the average daily requirement as recommended by the Committee on Nutrition of the National Research Council.

BETWEEN-MEAL FEEDINGS IN INDUSTRY

No doubt we have all experienced that "let down" feeling that occurs in the middle of the morning and afternoon and that is alleviated by a nourishing drink (or one not so nourishing) and a snack of food.

"All-out production" is taking its toll in taut and tired nerves, weary muscles, aching brows, and fatigue. Anything that can compensate and at the same time benefit the individual should be welcomed, for not only must bodies be kept fit, but morale must also be in tune if success is to be attained and our fighting men properly equipped. Industry can do this by offsetting the long, tedious hours with a refreshing pause of a glass of cool fruit juice or fresh fruit; a sandwich; milk, or in cold weather a hot chocolate or soup. These foods are high in vitamins and minerals and help to furnish the body with the protective foods as well as refreshing the body with necessary calories.

Haggard and Greenberg[4] have shown the effects of a carbohydrate meal that puts no burden on digestion and yet is a definite benefit to the diet. They state, "The average individual finds it beneficial to eat beween meals in that he gains some feeling of well-being, some relief from tiredness, and increased productivity; and while there are those who do not experience these benefits, there are others who find between-meal feedings an absolute necessity in preventing marked tiredness and decreased productivity."

Table 1.—A New Yardstick for Nutrition

Daily allowances recommended by the Committee on Foods and Nutrition, National Research Council

	Calories	Protein, gm.	Calcium, gm.	Iron, mg	Vitamin A, I. U.	Thiamine (B_1),* mg	Ascorbic Acid (C),* mg.	Riboflavin (B_2), mg	Nicotinic Acid, mg.	Vitamin D, I. U.
Man (70 Kg.)										
Moderately active	3000	70	0.8	12	5000	1.8	75	2.7	18	**
Very active . . .	4500				.	2.3	.	3.3	23	
Sedentary . . .	2500				. . .	1.5	.	2.2	15	
Woman (56 Kg.)										
Moderately active	2500	60	0.8	12	5000	1.5	70	2.2	15	**
Very active. . . .	3000		.		. . .	1.8	..	2.7	18	
Sedentary. . . .	2100					1.2	..	1.8	12	
Pregnancy (latter half)	2500	85	1.5	15	6000	1.8	100	2.5	18	400–800
Lactation.	3000	100	2.0		8000	2.3	150	3.0	23	400–800
Children up to 12 years										
Under 1 year. . .	100 per Kg.	3–4 per Kg.	1.0	6	1500	0.4	30	0.6	4	400–800
1–3 years	1200	40	1.0	7	2000	0.6	35	0.9	6	
4–6 years.	1600	50	1.0	8	2500	0.8	50	1.2	8	**
7–9 years	2000	60	1.0	10	3500	1.0	60	1.5	10	
10–12 years	2500	70	1.2	12	4500	1.2	75	1.8	12	
Children over 12 years										
Girls 13–15 years . .	2800	80	1.3	15	5000	1.4	80	2.0	14	**
16–20 years . . .	2400	75	1.0	15	5000	1.2	80	1.8	12	
Boys 13–15 years	3200	85	1.4	15	5000	1.6	90	2.4	16	**
16–20 years . . .	3800	100	1.4	15	6000	2.0	100	3.0	20	

Note: A gram in the international metric system of weights and measures is about one twenty-eighth of an ounce. A kilogram, which is 1000 grams, is equal to 2.2 pounds avoirdupois. A milligram is one thousandth of a gram. A calorie is a unit of measurement used to express the heat-producing or energy-producing value of food.

* 1 mg. thiamine equals 333 International Units; 1 mg. ascorbic acid equals 20 International Units; (1 International Unit equals 1 U.S.P. unit).

There are objections to between-meal feedings that present handicaps to the employer. Unless the feedings are easily accessible, valuable time is consumed. If, however, a cart of assorted nourishing, hot and cold beverages can be rolled around through the work shops, little time is taken and much good accomplished. Canteens that offer tomato juice, bottled milk, and fruit juices are excellent adjuncts for industrial plants and are helping to solve the "beverage" problem. Soft drinks are now being frowned upon as offering nothing to the dietary but sugar—and most of the American diets are too high in sugar as it is.

In connection with this problem the report of the Committee on Nutrition in Industry of the National Research Council, "Practical Considerations for Industries Interested in the Nutritional Health of Their Employees," lists the major causes of nutritional inadequacy among workers in this country under four headings: (*a*) poor food habits; (*b*) poor commissary; (*c*) economic factors, and (*d*) metabolic stress. The significance of *poor food habits* has already been indicated, and *poor commissary* and *economic factors* are so obvious as to need no further comment.

Since *metabolic stress* is particularly evident in those on shift work, one important problem in the field of proper nutrition for workers is making sure that these workers get a well-balanced ration. Especially is this true with those on *swing shifts*. Changing hours of work every few weeks means disturbance to hours of sleep and regularity of meal times. Some adjust very poorly to these variations. To be sure, in large numbers of individuals this is not a disturbing situation. but for many it brings on undue fatigue, nervousness, loss of appetite. indigestion, and loss of weight. The general observation seems to be that they sleep less while on the day shift but eat more, and sleep more when on the night shift but eat less. The disturbance to health can be avoided only by very careful adherence to an *eating time schedule*, comparable to the usual meals of day workers, with care as to selection and quantity of foods.

PROGRAM

To bring the matter of nutrition in industry home to many of us, what sort of a program can be outlined which will be helpful in almost any industry anywhere? It can be divided in the following manner:

(*a*) The value and place of trained cafeteria managers.
(*b*) The importance of proper and adequate menus.
(*c*) The education of workers regarding proper foods.

(a) Trained Personnel

Strange to say, there are few accredited dietitians looking after the nutrition of employees in industry, though the Army, Navy, Air Lines, Home Bureaus, schools, colleges, hospitals, and welfare organizations have long been cognizant of their contribution to mankind. Industry, busy with production, has concerned itself primarily with brawn and brain, while the "*stomach*" of the employee has gone unnoticed, and he has been left to his own devices in getting his "three square a day." The fact that he has done a pretty poor job of this, in light of our advancing knowledge, is just beginning to dawn on our consciousness. In addition, we are beginning to learn that his diet inadequacies have affected his working efficiency, his absentee days, his incidence of accidents and his general physical and mental well-being.

Dietitian.—Industry has a problem child on its hands. It is the problem of seeing that workers, upon whom so much depends for our country's war needs, are able to obtain right foods at least while on the job. You will recall the effort in England to provide for workers in their one meal on the job as much of the necessary daily requirements as possible. Certainly one step toward the best answer, and one which would alleviate most of the headaches for management, would be to have at least one person trained in Home Economics, preferably a dietitian, heading the cafeteria or canteen service, or at least available as a consultant. The advantages of such a person in industry are apparent. The dietitian should be made responsible for the entire service of food including purchasing, planning, preparation, serving, and cost accounting. She should also "hire and fire" her own employees and outline

their working schedules. Her food budget should be flexible enough to allow for a rise in food costs and the necessary price adjustments.

With a trained person heading the industrial cafeteria, food will be more wisely purchased and the charge to the employee less. Standardized recipes will be used in food preparation and menus planned that will be nourishing and adequate and at the lowest possible cost. Offering the employees a *complete plate lunch* is the best method of selling good nutrition. This should include a meat or alternative, potato and vegetable, beverage, bread, butter, and dessert. Cafeterias that offer a hot plate lunch of this type at 25 or 30 cents usually do an excellent business. The company may lose a few dollars, but they are repaid in employee satisfaction and better nutrition.

(b) Provision of Proper Menus

Industry should be "concerned primarily with the foodstuffs served on the premises of the industrial plant, including not only mid-day lunches but all food and drink obtainable by the employees on the premises, through the active or passive cooperation of the plant management. Industry can also render a valuable service by calling upon local health authorities actively to supervise those restaurants and lunch stands which habitually crop up in the environs of expanding industrial concerns."[1]

"Measures designed to improve the plant commissary should include the elimination, in so far as feasible, of vitamin-free and vitamin-poor foods like candy, sugar, highly-milled non-'enriched' cereal products, soft drinks, and alcohol. Lunches and supplementary feedings should be designed to furnish the employee with the greatest possible proportion of his daily nutritional requirements.

"In estimating cafeteria menus it is well to bear in mind that to meet the recommended daily allowances of the Food and Nutrition Board of the National Research Council requires the daily consumption of *at least* one pint of milk; two servings of potatoes; two servings of fruit, one of which should be a citrus variety or tomato; two vegetables, one of which should be leafy, green or yellow; one egg; one serving of meat, fish or poultry; a cereal dish (whole grain); whole grain, or 'enriched' bread at every meal; and butter or fortified oleomargarine, the remaining calories to be supplied by a choice of vitamin-rich foods.

"It is extremely important also that foods be prepared in such a manner that they are attractive and palatable, and that minimum losses in their vitamin and mineral content occur."[1]

The importance of proper nutrition is being recognized in the Army as never before. In spite of all the difficulties involved, Mary I. Barber, Food Consultant to the Secretary of War, says, "The American soldier will be well fed—better fed, in fact, than at least 60 per cent of the people in the United States and better than any other fighting men in the world."[6] Out of headquarters in Washington each month go properly balanced menus to guide the army cooks.

(c) Education

One thing which every industry, large or small, can do is to carry on some sort of a systematic plan of nutrition education. With all the valuable printed material available from various reliable sources, there is no excuse for at least not exposing employees to some form or part of it. Before the war is over, we shall all become more food conscious. Industries have an excellent opportunity to spread the gospel of right nutrition.

There are two ways of approaching the problem of teaching workers the fundamentals of good nutrition: first, by printed illustrative material for mass education, and second, by individual and group instruction.

(1) Illustrative Material for Mass Education

Pamphlets on Nutrition are varied in scope and can be taken into the home. These can be obtained from various sources—Consumer's Guide, Bureau of Home Economics, Metropolitan Life Insurance Company, and commercial organizations like the National Live Stock and Meat Board, Dairy Council, and other similar ones.

Bulletin Boards should be placed in strategic locations: rest rooms, hallways, elevators, and, of course, the cafeterias or dining rooms.

Exhibits are one of the oldest methods of presenting nutrition material. These can be in the form of posters, miniatures, food models, actual food displays, Kodachrome transparencies or movies.

An Employees' Magazine or paper that is issued periodically reaches the greatest number of people and is carried into the home where wives, mothers, children, and friends can read its message.

Doctors, scientists, dietitians and nutrition workers must do all in their power to combat the nutrition fallacies that abound over the ether waves, in periodicals and in papers. The government is making every effort to correct erroneous information and start people on a sound nutrition program that will build man power, raise morale, and develop a country of courageous, strong, healthy individuals.

Diet Lists can be given out by the company doctors, nurses, or dietitian.

their working schedules. Her food budget should be flexible enough to allow for a rise in food costs and the necessary price adjustments.

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"It is extremely important also that foods be prepared in such a manner that they are attractive and palatable, and that minimum losses in their vitamin and mineral content occur."[1]

4. The major causes of nutritional inadequacy in this country are listed by the Committee on Nutrition in Industry of the National Research Council as follows: (*a*) poor food habits; (*b*) poor commissary; (*c*) economic factors; (*d*) metabolic stress.

5. A scientifically planned program is the only solution to this problem and should include: (*a*) Trained personnel; (*b*) Provision of proper and adequate menus; (*c*) Well-integrated efforts at mass education. Real strides can be made toward better nutrition, better morale, and better production by a better program. As Dr. Victor Heiser says, "Today we know enough about the importance of nutrition to be able to say that the number of planes, guns, tanks that come out of the nation's plants is determined largely by what the nation's workers put into their stomachs."[7]

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A week's set of suggested menus with normal, reduction, and underweight diets has proved helpful. Diet lists should be simple because too many are so detailed in information that anyone attempting to plan a day's menu gets confused and does not know quite how to juggle the array of foods to form a balanced diet.

Movies are effective especially when they are in color. Fruit and vegetables in black and white are not as appetizing as when seen in their natural colors. In the last two years, some excellent educational films have been produced and are available for use at very little or no cost.

(2) Individual and Group Instruction

The second method of presenting nutrition advice is through individual and group instruction, and necessitates having a trained nutritionist. Illustrative material can be secured and presented, as has already been mentioned, from a number of excellent sources. Personal instruction, either individual or group, requires a specialist. Unquestionably, individual instruction is the ideal way to achieve the best results. So many problems—mental, physical, and economic—enter into the picture and cannot be taken into consideration except through personal interviews. Underweight and overweight employees can be referred to the nutrition adviser by the doctors and nurses. Many will come to the medical department of their own volition. Individuals trying to gain or lose weight need encouragement and guidance. The best results seem to be obtained from regular and frequent interviews. If there is no nutritionist on the staff, it is quite possible for nurses in industry to make a specialty of this subject and act as counselors in giving individuals advice as to proper diet.

A prevailing misconception among the uninformed which should be overcome is that workers are not interested and will not heed advice. This depends largely on the approach used. To the contrary, men and women have seemed glad to consult with the nutrition adviser. So successful has this practice been that I feel it is one of the best methods of putting across an educational program.

SUMMARY

An effort has been made to emphasize the following points:

1. Industrial workers are not as well fed as they can be. There are dietary deficiencies. Some significant surveys have been made, others are being made, which bear out this statement.
2. Vitamin deficiencies do exist and vitamin supplements are valuable.
3. Between-meal feedings have a place in an industrial program.

4. The major causes of nutritional inadequacy in this country are listed by the Committee on Nutrition in Industry of the National Research Council as follows: (*a*) poor food habits; (*b*) poor commissary; (*c*) economic factors; (*d*) metabolic stress.

5. A scientifically planned program is the only solution to this problem and should include: (*a*) Trained personnel; (*b*) Provision of proper and adequate menus; (*c*) Well-integrated efforts at mass education. Real strides can be made toward better nutrition, better morale, and better production by a better program. As Dr. Victor Heiser says, "Today we know enough about the importance of nutrition to be able to say that the number of planes, guns, tanks that come out of the nation's plants is determined largely by what the nation's workers put into their stomachs." [7]

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A WARTIME SURVEY OF INDUSTRIAL PSYCHIATRY

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THE emergencies of our wartime industrial production are so clearly recognized that it is no longer necessary for a psychiatrist to underscore the obvious national dangers which may result from the lack of proper safeguards and controls for maladjusted emotions. Nor does he now have the time to show proof of greater efficiency and larger profits which would result through a more intensive psychiatric conservation of manpower. The dangers are immediate. Hysteria, excessive fatigue, emotionally maladjusted personalities, the employment of marginal labor groups, the crudities of green authority, racial antagonisms, sabotage, propaganda, inadequate protection, uprooted social patterns, subnormal housing, and physical fear of bombardment—these are problems and dangers fully admitted and the tools and technics for meeting them must be coordinated and more generally understood. With the plea that national emergencies do not wait upon niceties of medical courtesy, the attempt is made here to state flatly some of the defects of our psychiatric tools, some avenues of action, and the general limits of the emotional problems in industry.

PECULIARITIES IN THE DEVELOPMENT OF PSYCHIATRY

The relatively recent and rapid development of psychiatry as a separate medical field has deposited certain peculiarities in present-day practice. One would suppose that the ideal development of any medical specialty ought to stem out of careful laboratory exploration, extend through years of graduated application tested by adequate control groups, and emerge, finally, with a therapy modulated, analyzed, and

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enthusiastic excesses over minor advancements, the premature conclusions unhitched to established technic, the posturings of career men, and the factional quarrels of rival theorists. And, to complicate matters, there were, as usual, the newspaper misrepresentations which make scientific progress so uncommonly difficult in this nation. All this was understandable enough, but what is not too often appreciated today is that these stages of growth deposited peculiarities which, through long familiarity, have almost attained the sanction of fundamental premises. Let us consider just a few of these.

Custodial Function of Early Psychiatry.—Prior to the entry of the United States into the first World War, psychiatry was almost entirely custodial in function. Segregation at private and public expense was the accepted answer to most cases of mental ill-health. Now the medical men who took care of the inmates of those institutions had entered upon a peculiarly cramped professional area. Despite their ambitions and their efforts, the possibilities of experimentation were tied down to the known insane in publicly shunned institutions where the pressure of an adverse social attitude and the severance from environmental factors put almost insuperable difficulties in the way of effecting a cure. The earlier theorists could only deduce backwards. The early work of Dr. Adolf Meyer and his group did much to prevent an apathetic acceptance of this restriction. The concept of "psychobiology" jolted the practitioners out of their institutional fastnesses and induced them *to examine the patient and not the disease.* Yet, even so, their cases had most often reached a final stage before they even saw them, and the evidence of previous environmental pressures was tenuous and stereotyped. It was a tantalizing situation, and one which led at times to generalizations not adequately backed by complete case histories. For a time the avenues of speculation seemed blocked, and an undue emphasis was placed upon the *curious*, the *abnormal*, and the *clinical*, an emphasis which exists only slightly diminished today.

Effect of World War I.—A wider field for investigation was opened up by the entry of the United States into the

with all aberrations tabulated within precise tolerable limits. Neither psychiatry itself in general, nor the specialty of industrial psychiatry in particular have had the good fortune to grow through such an orderly development. The accidents of history, the human reaction, lay and medical, to the sombre nature of the material involved, and the perhaps not-so-curious susceptibility of the investigators themselves to mild attacks of occupational disease, have all brought about an uneven and spotty development, a lack of focus which has militated against the mass application of psychiatry in ordinary preventive medicine.

A glance at that growth may make my point clearer. Psychiatry in general may operate on *four levels*. These in their historical sequence are:

1. *Custodial*—state institutions, specialized military hospitals, and private sanatoria.
2. *Therapeutic*—the derivation and application of therapies and technics aimed at cure and alleviation of mental and emotional illness.
3. *Preventive*—mass application of mental hygiene; protections of the "normal" from undue stress; control of borderline susceptible pre-clinical diagnosis; control of social and industrial factors to forestall mental and nervous breakdowns; setting up of tests for differentiation of mental and emotional types; co-ordination of all facilities to insure mental and emotional health.
4. *Directional*—the shaping of environmental factors to produce desired mental and emotional type or general level; used offensively in the control of subjugated peoples and in the production of propaganda for enemy consumption; used defensively for the establishment of morale and efficiency.

These four levels are still marred by the crudities of newness. Custodial psychiatry, the oldest, has shown the most solid advances, but on the therapeutic level rival theorists and specialists still have their acrid differences. In its preventive phase psychiatry still awaits a mass application to industry and education on a scale comparable in any way to that in the military services. On the directional level the limits and possibilities are so nebulous that so far the action has been frankly and largely imitative and based on deductions from Axis procedures.

In its earlier days, psychiatry exhibited, quite naturally, the mistakes of any beginning movement. There were the usual

imate technic were seized upon by the unscrupulous and a new gullibility was exploited. Naturally, public opinion soon reversed its field. Laymen became vocal in their criticisms, the psychiatrist *per se* was lampooned unmercifully, and criticisms were leveled indiscriminately at guilty and innocent alike. Lay objections have, as medical men know, a most irritatingly quasi-pertinency that requires a full statement of basic aims to refute—and lay criticism, needless to say, waits not for answer. All this resulted in a still unallayed popular suspicion, a vast amount of dated and empty wordage, and a still habitual glibness of explanation and diagnosis.

This earlier journalistic phase soon settled to the respectable but seriously restricted area of the psychiatrist's office. There the patients came for professional treatment, but the length, the cost, and the inconvenience of the treatments limited economically the class of person who could benefit. Psychiatry, in fact, became something of an upperclass fad, and the type of cases treated led (and still leads) to an overemphasis upon the mental ills of a numerically minor social group; the megrims of surfeit and glandular boredom are not exactly typical of industrial America. But the leisurely therapies persist, and back of no small amount of present investigation is the questionable assumption that the average patient has personally the social and economic power to alter his environmental pressures.

Preventive Psychiatry.—The preventive phase of psychiatry probably had its formal beginning in 1909 with the establishment of the National Committee for Mental Hygiene, but the Committee's work until after the World War was largely educational and organizational. The first large-scale effort at prevention was through the *Child Guidance Clinics*, the pioneers being those of Dr. William Healy in Chicago as early as 1909, and the Judge Baker Guidance Center in Boston, 1917. This work was extended to the prevention of childhood delinquency, especially the Commonwealth Fund Five Year Program begun in 1922. The efforts of the movement have resulted in a new attitude toward legal offenders, perhaps best illustrated, in theory at least, by the "Behavior Clinic" of Pittsburgh, a permanent board of experts set up to look

World War when an attempt was made to apply psychiatry on a mass basis to the armed forces. Here, for the first time in this country the scientific explorer could see the inception, the progress, and the closing phases of a mental ailment, and for the first time he had the authority and the numerical scope with which to control his data and reach reasonably accurate conclusions. The *range* of mental ills and mental types were shown up on an identical environment and tested by the same brutally primitive fear of death. Through the sympathetic influence of Surgeon-General Ireland, divisional psychiatric officers were appointed and the task of controlling, gauging, and adjusting the indiscriminate mass of men was begun. After July 1, 1918, these officers were given the power to reject for overseas service those whom they judged unstable and emotionally unfit. Thus standards of procedure were set up and given a practical testing. This authority and opportunity led to a close examination of mental data. Many of the taboos surrounding the mentally unfit were shattered, and, as a by-product of a social upheaval, *psychiatry became more generally therapeutic and not merely custodial.*

Post-war Psychiatry.—The power for social advancement inherent in the mass method, however, was passed by almost unnoticed, and the lively pertinency of the Surgeon-General's Report went almost unrecognized until the late thirties. For, by a series of literary accidents, psychiatry became in the post-war period a most unfortunately popular subject. Under the popular acceptance of Freud, Adler, and Jung, mental ills became matters of common conversation. A garbled nomenclature hissed about the land. Dream symbolism, psychoses, incipient paranoia, inhibitions, phobias, and tropisms were discussed learnedly to prove one's social position and general awareness. The genuine psychiatrist was mobbed by conversationalists, and he never did succeed in making the public understand that an honest professional had to *prove* his facts and *define* his language.

Psychiatry in this middle period came closer to being scuttled by popular enthusiasm than it ever had been in the earlier period by lack of opportunity to experiment. Quacks and opportunists found rich pickings. Distortions of legit-

ing two major conclusions: (1) that tests and batteries of tests measure different things in different situations, and in order to be of value they must be applied specifically to one group and the results explored exhaustively by statistical analysis for recurrent relationships, which relationships may or may not turn out to be those which the tests were intended to measure; (2) that the qualities measured by the tests were not static, and that some functional element not measured by the tests impaired predictability. *By reason of these conclusions attention has shifted in industry toward the possibilities of medical analysis, especially of neuropsychiatric procedures.* Safety workers and other industrial control groups have altered their programs to include some application of psychiatric technics, but the progress from 1934 to 1941 has been, in general, a slow one of group education and technical exploration.

The Industrial Worker's Problem.—Industrial peculiarities have already left their mark on industrial psychiatry, and they may continue to operate as obstacles to a realistic application. Due to complete absorption with the physical and mechanical problems incident to industry's mushroom growth, there has been a tendency to neglect the individual worker's hunger for personal significance and dignity, to ignore the paradox which every industrial worker faces: outside the factory gates he is a fully rounded being who is expected to like children, vote intelligently, understand our nation's foreign policy, and make every great problem his own; inside the factory gates he is too often expected to employ only a fraction of himself, to become an impersonal unit, hard and selfless, working through his best years with another man's tools on a product which will not bear his name and whose function he rarely comprehends, looking forward to the pay envelope with which he, too, can *buy* what he wants in a market where "labor" is just another commodity. This *economic and engineering conception* of a worker as a modified handle to a machine dies hard; only the statistical proof of greater efficiency and greater savings because of a more humane industrial attitude has been effective in combating it.

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thoroughly into cases of first offenders, mental defectives, sexual offenders, and all alcoholic and narcotic cases. Speaking of this clinic Judge Ralph Smith of the Common Pleas Court said: "When a judge passes sentence upon a defendant without having as complete knowledge as possible regarding that offender's background, education, environment and motivations which prompted the act against the interest of society, that judge is merely guessing as to the proper disposition of the case."[1] Such an attitude represents a great advance, but speaking of the general field of psychiatry, these efforts are still marked by undue emphasis upon the abnormal, the marginal, the social incompetents. The technics are adjusted to that level, and back of them is the irresistible force of legal power, declared or merely potential.

Industrial Preventive Psychiatry.—As early as 1916, psychiatrists became aware of the possibilities for preventive action and controlled data in the mass of the industrially employed. In that year the Cheney Silk Company conducted a research on the costs of emotional maladjustments among its employees. In 1917–1920 Dr. E. E. Southard secured the backing of the Engineering Foundation for a psychiatric examination of personnel problems, and in one survey found that 62 per cent of more than 4000 cases observed reached the discharge status through traits of social incompetence rather than occupational incompetence. In the early twenties Dr. C. M. Campbell and Dr. H. B. Elkind did pioneer work in the Boston area, and in 1922 the Metropolitan Life Insurance Company started its psychiatric service for employees which continues today. From 1924 to 1929 Macy's Department Store in New York City, employing about nine thousand persons through this period, carried through investigations of maladjustments to sales and clerical employment.

After 1924 there were only sporadic attempts at industrial application, and these, for the most part, were inadequately conceived and executed. The next major impetus came from industrial personnel groups in 1932 when they began to apply psychological concepts more rigorously to their perennial problems of labor turnover and labor placement. Out of their experience with tests and personality ratings there are emerg-

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So, in summary, psychiatry and especially industrial psychiatry, exhibit the irregularities natural to a rapid growth. These irregularities must be taken into account in any plan to apply a program to industry, and the war emergency has made such an application imperative.

THE NEW SOCIO-MEDICAL SYNTHESIS

Our national productive system has been dislocated by a gigantic war effort whose further potentialities can only be guessed at. The horizons beyond our emergency are pregnant with fundamental cultural changes. Victory most likely will bring a rapid and unprecedented world expansion of commerce and industry in which American organizations will enact the leading roles. At present, though, caught as we are in the confusing currents of national change, most of us are conscious merely of new patterns emerging from the old and of old standards sinking out of sight into the new. We do know one thing certainly: at the end of these troublesome times American industry will be a vastly changed organism. In all probability it will be a better organism, for into these years is being packed a great deal of growing. Movements and reforms which would ordinarily come about slowly, if at all, are rushing up apace.

The motive power for these social changes comes from two sources which have curiously implemented each other; first, the shock and upheaval caused by the depression years; second, the galvanic impetus of a national change to a defense and then to a wartime economy. The first gave rise to a broad interest in social casualties; it worked from the general to the particular, from the periphery to the center of its problems, and, prior to the war entry, was slowly growing toward a synthesis of *all* approaches—the political, the legal, the sociological, the psychological, the educational, and the medical. The second source, the change to war economy, let loose irresistible energy at the center, the heart, of industrial problems—the mills and factories themselves. The emphasis here is upon the immediate, the concrete, the particular, upon the complete utilization of industrial resources, with all action subject to a central plan and a central emergency. From both sources have come the same aims: the conservation of manpower, the rehabilitation of marginal labor, dynamic activation of the apprentice system, the testing and use of individual capacities, and a direct concern with mental and emotional health of industrial workers and their families. Thus, *the aims of a social reform movement have become basic rules of national self-preservation.*

Present-Day Facilities for Studying the Workers' Problems

So the searchlights of many different methods and forms of analysis have been turned upon the industrial worker and his problems. Here are some of the methods and agencies within industry itself.

I. Personnel Management working through:
   1. Training programs.
   2. Morale maintenance.
   3. Safety engineering.
   4. Time and motion studies.
   5. Job analyses.
   6. Skill ratings.
   7. Promotional standards.
   8. Accident compensation, sickness benefits, group insurance and pensions.
   9. Nutrition control, canteens, and commissary.

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7. Sociological research on racial minorities and the migratory worker.
8. Government, and state activities and studies on Civilian Conservation corps, employment agencies, National Youth Administration, Works Project Administration researches and writers' studies, unemployment relief, and the research and records of the Public Health Service.
9. Studies in delinquency, child-guidance, and adult education.
10. Social service case work and reporting, including psychiatric service.
11. Housing reports and settlement projects, private and governmental.
12. Medical and legal aid clinics.
13. Medical studies in mass nutrition, morale, women and older workers in industry, group medicine, and preventive measures.
14. Military measures and analyses of medical facilities, housing, labor placement, industrial productivity, and morale protection.

The findings pouring in over these avenues of inquiry have emphasized one basic doctrine: the indivisibility of the worker as a social and industrial unit.

Importance of Worker's Personality

It would seem that the personality of any one industrial worker is a unit, and, within the limits of good mental health, nondivisible. It is the sum total of all his traits, interests, qualities, talents, and training and pressures from all areas of activity demand action from the whole personality. When the personality reacts, it reacts as a unit, whether the stimulus comes from within or from without the industrial setting. The logical compartments of "worker," "father," "citizen," "debtor," "machinist," "home-owner," "accident victim"—these are handy abstractions only; they do not describe the living personality. Moreover, the worker's personality as a unit is constantly in flux, varying in effectiveness and control with age and development crises; as a unit it is susceptible to pressure from the whole social area—home, family, community, nation, race, religion, conscience, industrial group, and whatever. The industrial fraction of the worker's life cannot explain him, and it does not necessarily isolate him at any time from other parts of himself. The personality of the worker can, of course, achieve various degrees of abstraction, but these levels can be achieved without danger only when the whole personality is healthy and relatively free of emotional conflict. When adverse pressure does split off any part

II. Industrial psychology, tests and standards for:
  1. Mental defective and intelligence levels.
  2. Mechanical aptitudes and abilities.
  3. Personality surveys.

III. Industrial medicine through:
  1. Care and prevention in injuries and sudden illness.
  2. Examination for physical fitness for industrial work.
  3. Job analysis for physical fitness factors.
  4. Industrial hygiene and the control of occupational diseases and hazards.
  5. Visiting and first-aid nursing services.
  6. Psychiatric services:
    (*a*) Detection and elimination of psychotics.
    (*b*) Preventive interviews and examinations of emotional maladjustments.
    (*c*) Standardization of industrial fitness for the functionally and degeneratively diseased.
    (*d*) Analysis of accidents, avoidable absenteeism, personality clashes, monotony, fatigue, labor turnover, and morale lapses.
    (*e*) Promotional standards and personality typing.
    (*f*) Standards for women workers.
    (*g*) Preventive action at age and development crises.
    (*h*) Industrial rehabilitation of the injured and convalescent.

IV. United States Public Health Service, Industrial Hygiene Division through:
  1. Research in occupational hazards and their control.
  2. Regulations, standards, and precautions for industrial disease.

V. United States Government subsidized "trainee" programs for war workers by:
  1. "In-plant" apprentice programs and refresher courses.
  2. "Out-plant" use of local educational facilities and personnel.

In addition to these avenues within industry the whole battery of the social sciences has of recent years been uncovering very important data on the peculiar problems of the urban industrial areas through:

1. City, town, state, and regional social surveys.
2. Town, city, and state planning commissions.
3. Industrial surveys: technological displacement, labor mobility, and labor availability.
4. Economic studies in wage and hour analysis, living standards, industrial function and development, and in the migration and placement of industry.
5. Socio-anthropological surveys in class alignments and class behavior patterns.
6. Developments in social and structural psychology.

7. Sociological research on racial minorities and the migratory worker.
8. Government, and state activities and studies on Civilian Conservation corps, employment agencies, National Youth Administration, Works Project Administration researches and writers' studies, unemployment relief, and the research and records of the Public Health Service.
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of a worker's personality, that worker is sick and needs medical attention.

It follows, then, that preventive social and medical action should be based upon a *complex and inclusive analysis*. Partial technics, while they may give individual aid, cannot be certain of their findings and cannot hope to attack the fundamental causes of maladjustment. Some notion of the compulsions and escapes in the industrial world may be gained from the accompanying chart (Fig. 158), which, it will be noted, is keyed primarily to the level of the skilled worker. Under social and industrial pressure the individual is malleable to a point, but there is an internal driving power that needs fulfillment and, above all, self-respecting *use;* dissatisfaction and maladjustment will turn that power into escape channels which lead, most often, to social incompetency.

Role of Industrial Physician

The amalgamation of the various avenues of inquiry and action into a single synthesis for preventive action is possible and practicable. The crux of the matter rests in the *centralization of information and action*, the *definition of terms*, and the *evolution of basic minimal tests for social and industrial fitness*.

These objectives can be met with little more confusion and change than is already inevitable in the co-ordination of all agencies to the central war effort. What is needed is a rallying point, a fulcrum for action, and in this regard no other agency can have the effectiveness of the industrial physician already at home in the area of application.[2] Many indications point to him as the means of effecting a broad program, and these will be developed in a later section. It is sufficient now to note that general medical advances have disposed rather thoroughly of any dichotomy of somatic and mental medicine; the field of the "G.P." has broadened and deepened in effectiveness. *The industrial physician is a general practitioner in a very important area*, an area which cannot and will not support the specialist. The psychiatrist *per se* will probably have no place in industry; psychiatry in its preventive phases does and will have such a place.

The Physician and a Preventive Program.—At present the concept of social and industrial "fitness" seems the only workable standard for a scaling of employee-environment evaluations. Five or more years of successful adjustment to industrial working conditions ought to be taken as proof of the individual's power to meet ordinary strains and tensions. Mental and physical defects which have not incapacitated the worker during that period and which do not have an immediately degenerative future ought not to be given heavy emphasis in any analysis. Emotional maladjustment after such a period ought to be considered temporary in nature, and the employee should be retained and routine analysis instituted for abnormal environmental pressures and conditions. Such procedures as these would enable a preventive program to adhere to strictly *pragmatic* measures and would minimize the moralistic and perfectionist attitudes of mind which color present analyses.

Again, in present industrial practice there is no maladjustment until the employee draws the attention of the foreman, the personnel office, or the industrial doctor; that is, there is no evidence of individual maladjustment until that maladjustment has reached a late stage of development. The *synthesis* of methods discussed here would aid tremendously in forestalling maladjustments before they reached the objective stage, for industrial danger signals often appear before the individual patient appears. Lowered efficiency, disaffection, spoilage, vandalism, horseplay, increased labor turnover, high accident ratings, continued absenteeism, excessive fatigue, lack of apprentices—these call for a general casting about for maladjusted personalities (especially in key positions of authority) and for abnormal environmental pressures. A truly preventive program would call for a great deal of effort in what might be called "pre-clinical" areas, the generalized, partly-formed symptoms—physical, mental, emotional, industrial—which are preliminary to those of actual illness. Thus, the area for speculation is broadened to include social, economic, group, and industrial forces in dynamic action.

So, too, in the handling of the special *war types* of sick personalities which have begun to emerge in this country and

companies (which comprise more than 90 per cent of the employers of industrial labor) must depend upon part-time services. The medical personnel thus carries a dual role; it is made up of privately paid, privately employed individuals, but it functions as a professional entity parallel to but not coincidental with other branches of corporative activity and authority. Its ends and methods are entirely medical, but the corporation employing that service is not bound to act upon its recommendations, especially when these run counter to the practical function of a business enterprise. Such a position gives industrial medicine a wide freedom of inquiry, but ties that freedom down to a *healthy practicality of action.* Medical concepts should be adjusted to the realism of industrial production.

By and large, the medically undesirables are also those of industry. In the specific field of psychiatry the types of dysfunctions and maladjustments will always give the employer trouble. Low physical, social, and industrial competence are closely related, and the high tension of their adjustment to environment makes their grip on security even more precarious. Most American workers of average competence have made their adjustments to the compulsions of industrial living, and, if their equations are not upset too radically, they will continue to function smoothly and consistently with only normal lapses for illness and age crises. In any large organization, however, there will be at any one time a fairly constant 20 to 25 per cent of the workers who for chronic or temporary causes are unable to bear efficiently the stresses of industrial work. These may be classified as follows in the sequence of their numerical incidence:

1. True psychotics: rare instances and eliminated at once from the industrial scene.
2. Subnormal mentalities: not numerous, and once adjusted to proper work they are not troublesome.
3. Psychopathic or borderline personalities: difficult to adjust, and once having reached positions of authority hard to detect and very dangerous to morale and efficiency.
4. Neuropsychiatric conditions: alcoholics, syphilitics, epileptics, postencephalitics, preseniles, and so on.
5. Psychoneurotics: more numerous but chiefly of the anxiety states susceptible to treatment.

in England. Their symptoms are social ones and can be detected most readily by a synthesis of the various methods of analysis. Here are a few that have been tentatively identified[3]:

1. The upset ritualist who having lost his balance wheel wears a ruffled temper until he can surround himself with a settled routine.
2. The excited enthusiast who burns himself out quickly and does his best to persuade others to do likewise; unaware of his fatigue he is trapped by his irritated nerves into assuming more and more work and responsibility until a breaking point is reached.
3. The emotional expansionist, usually a quiet and even prim fellow who becomes obscurely excited by war dangers and plunges into all sorts of uncharacteristic excess including drunkenness and wasteful spending.
4. The noveau-bellicose who suddenly finds a voice and proceeds to exaggerate every topic with a bloodthirsty animosity, his government and the war-effort included.
5. The deaf-static who is deeply alarmed by the turbulency and danger and yet closes his mind to them by hugging the familiar things of a safe existence so feverishly that there is no juice left in them for him.

Obviously these are behavior patterns and not mental or emotional types. They are no less important for all of that, and the detection and care of them is extraordinarily difficult through the present dispersed procedures.

Thus in these and many other ways the amalgamation of the several avenues of inquiry would provide new controls and new standards. Nor is such concentration of present methods merely desirable theory. At least one major industrial company is at present taking steps toward a fundamental renovation of its medical services in order to secure a more unified program of action.

THE PSYCHIATRIC BULK IN INDUSTRY

The general dimensions of the psychiatric problems in industry are roughly discernible. In establishing such limits, however, one must keep in mind the premises under which medicine must work in industrial establishments. There the role of medicine is purely advisory and preventive, with direct treatment of patients almost invariably limited to emergency conditions. The expense of such service is carried by private companies, and only the extremely large corporations can afford full-time, full-scale medical coverage. Smaller

to the extent of maladjustment. The number of neuroses following injury and the number of near and unreported minor accidents (probably fifty to each reported accident) have a direct relationship to the general causes of maladjustment.

These are normal figures; that is, they are those which one would expect in an industry operating under normal conditions and which had not yet applied any full scale psychiatric program. War conditions will do much to increase that estimate, but for immediate purposes it may be assumed that during the next three years one man out of every five employed in industry would profit from psychiatric guidance and control. The preventive aspect in war conditions is more difficult to measure; the man who did *not* contract whooping cough and who did *not* stay to dinner rarely attracts attention and cannot be numbered. But, in general, if the present accident rates, avoidable absenteeism, and behavior incidents do not increase considerably, the measures taken to minimize them during the war effort, whether military or medical, can be called eminently successful.

APPLICATION OF PSYCHIATRIC PRINCIPLES TO INDUSTRY

The immediacy of the industrial situation precludes for "the duration" any possibility of setting up a separate branch of personnel work to cover the social and emotional maladjustments of industrial workers. We must use what we have, and what we have is excellent from every point of view. The situation calls for an extension of the *scope* and the *responsibility* of the industrial medical doctor. He alone has the ballast of precise industrial knowledge and intimate acquaintance with the vagaries of physical and mental maladjustments on the practical level. He has the prestige of professional detachment, and his medical files are sacrosanct and impersonal. Since his capacity is purely advisory, his recommendations are neatly balanced by management's concern with efficiency and invested capital, and the theories of his medical fitness must survive the cold water shock of immediate practicality.

Maladjustments hit everywhere, from the lowest to the highest in corporate authority. And those in high authority are

6. Industrially maladjusted: the largest and most important group with the following subclassifications:
   (*a*) Personality clashes and habitual rule infraction.
   (*b*) Accident-proneness and habitual absenteeism.
   (*c*) Age crises of menopause and gerontology.
   (*d*) Development crises of endings, beginnings, lack of promotion, and the thirty-year social hurdle.
   (*e*) Rehabilitation cases of convalescent workers and especially of neurosis following accidental injury.
   (*f*) Malign environmental factors of anxiety and malnutrition.
   (*g*) Overstressed emotional compensations for physical defects and dysfunctions.

These classifications constitute the psychiatric "bulk" in industry. They represent, as has been stated, some 20 to 25 per cent of the total employed in any one corporation or industrial unit. This percentage indicates an average-in-flux for a five-year interval with allowance for labor turnover; it does not include nonrecurrent previously disposed cases. The estimate is based upon available figures from the twenty-two years of the Metropolitan Life Insurance Company's Home Office Service, the six years of the Macy's Department Store experiment, and analogies from military applications of mass psychiatry in the first World War, the Spanish Civil War, and the early experience in the present conflict. Individual variations for heavy and light industry, and for specific industries are not yet available, but, if preventive instances be included in the above figures, the expectancy of 20 per cent in these areas need not be considered too high.

Correlation of Psychiatric Cases with Industrial Accidents

A fertile field for additional verification of the psychiatric bulk may soon be had from the analysis of industrial accident statistics. Unification of the state standards for reporting them, and increasing co-operation among employers of smaller industrial groups are bringing in more accurate data. It is generally accepted that probably 80 per cent and more of the reported accidents are preventable, and of these perhaps one-half or 40 per cent are due to personal causes. When allowance has been made in this figure for the duplication by accident repeaters and the element due to casual carelessness, the residual amount should bear some functional relation

to the extent of maladjustment. The number of neuroses following injury and the number of near and unreported minor accidents (probably fifty to each reported accident) have a direct relationship to the general causes of maladjustment.

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Maladjustments hit everywhere, from the lowest to the highest in corporate authority. And those in high authority are

often immune to criticism and unaware of their own defects; for most human reasons their subordinates do not call them to correction. The industrial doctor in his professional capacity is subordinate only to his own conscience and his own professional obligations. He can, with freedom from criticism, turn light into corners too high for critical attention.

What is more, the industrial physician can *start an effective program immediately*, and that without the need of specialized training other than a sympathetic understanding of the new objectives. By conscious organization and recording of the many little graces which he unconsciously added to his practical role of industrial physician. he will achieve the core of information and the beginning structure which a later broad-scaled program can enhance and complete into a new industrial dimension. With his present equipment:

1. He can expect and trace the emotional complications which will come with every injury and illness he treats or advises on. Even a rough record of his findings may provide valuable data for generalizations.
2. He can *listen*. The therapeutic value of the interview is considerable, and the connection between surface symptoms of seeming irrelevance such as insomnia, "stomach trouble," vague neuralgias, etc., with serious underlying conditions may be detected in time for remedial action.
3. He can diagnose the industrial trouble spots—foremen, environment, fatigue, group maladjustment—by analyzing and reviewing his cases at regular intervals.
4. He can spot the accident-prone, the accident repeaters.
5. He can recognize the obvious maladjusted types, arrive at a rough classification and dispose of them by advising transfer, outside therapeutic treatment, or education of the employee in simple principles of mental and physical hygiene.
6. He can help prevent maladjustment by exercising actively his advisory function: (*a*) by repeatedly bringing to the attention of management each proven instance of preventable maladjustments; (*b*) by encouraging foremen, section heads, and supervisors to come to him for advice and information on employee problems; (*c*) by doing all he can to bring the extra-industrial factors to bear upon any interpretation of employee difficulties.
7. He can conserve manpower and uphold morale through *fighting* to secure medical immunity for the emotionally ill.

When twenty-five thousand industrial physicians start doing these things habitually, the curtain shall have been raised on a vast new medical laboratory in which the at-present dis-

persed technics of the medical and social sciences can be combined into a single powerful instrument of inquiry. That the new synthesis will be used in the interests of severely practical preventive medicine will not lessen a whit its possible contribution to general research. The necessity for a new classification of illness, the imperative need for shorter therapies, the opportunities for early diagnosis of the psychic forerunners of somatic disorders, the determination of crises and personality alternations other than the menopause, the examination of group reaction against the common and controlled background of industrial efficiency—all these should uncover valuable material for analysis and integration by those committed to pure research. Finally, and perhaps most important, the stimulus of the new information may bring about educational reforms which will produce a new medical entity, a fully implemented professional man who will not be merely a doctor-who-works-in-industry but an industrial physician.

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THE MEASUREMENT OF SICKNESS AMONG INDUSTRIAL WORKERS

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Whilst at first sight accidents, poisoning and a high occupational death rate are impressive, it cannot, I think, be doubted that the less dramatic side of the problem [of the health of the industrial worker] is, in fact, the more important—namely, the lost time and incapacity due to ill-health.

Sir George Newman. (From the Introduction to: Collis. E. L. and Greenwood. M. *The Health of the Industrial Worker.* J. & A. Churchill, London, 1921.)

INTRODUCTION

It has been recognized for some time that the worker's external environment is not limited to the environment presented by his work place, and that certain elements characterizing more or less the environment outside of his work place may be of significant influence on the worker's health. More recently this thought has developed further with the recognition that the health of the worker is a determining factor in the health of the community, industrial health thus becoming a matter of adult health and of tremendous importance in the field of public health.

With this change of viewpoint there naturally arose inquiries concerning the relative importance of the two environments with respect to the worker's health. Thus reference has been frequently made to the statement published by the American College of Surgeons that during 1936 among a group of 116 companies representing over 350,000 workers, 8.85 days per worker per year were accounted for by nonindustrial injuries and sickness, 0.59 day by industrial injuries, and 0.01 day by occupational diseases.[1] In other words the average worker lost during 1936 among this group of workers

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are by no means identical. In other words there are causes of invalidism and incapacity which can hardly affect a death rate.

The decision to adopt *time lost* as a measure of departure from health has, as was pointed out, automatically rejected minor ailments or defects and certain physical and mental impairments with none of which is there associated a loss of time. Thus the level of sickness absenteeism is measured, though not necessarily the level of sickness.

Two rates involving time lost have been constructed. These are commonly known as the *disability rate*, and the *severity rate*. The disability rate is the average number of days lost per year per worker, while the severity rate is the average number of days lost per absence. A third rate of considerable importance is the *frequency rate* or average annual number of absences per 1000 workers. For *preventive* purposes the frequency rate is a most useful one. Rates involving time while convenient for determining economic losses disclose nothing, for example, about the number of sources of infection. Thus the records might show three colds per year disabling on the average for five days each; another set of records might show one cold disabling for fifteen days. The three short colds present perhaps more of a problem to the plant and the community than the long one because of the possible effects from greater likelihood of spread of infection. In this hypothetical situation rates involving time would take into account only the days disabled, fifteen in each instance, and, consequently, would not differentiate the three-cold and one-cold experiences.

It is helpful to remember that the three rates referred to are related and that because of this relationship any one of the three may be obtained from the other two. For example, the disability rate equals the product of the frequency and severity rates divided by 1000.

COMPARABILITY OF RATES

Causes of Differences.—Let it be assumed that two plants have calculated a sickness absenteeism rate. If one rate is significantly larger than the other can it be concluded that the

about *fifteen* times as much time from nonindustrial injuries and sickness as he did from industrial injuries and occupational diseases.

A pertinent question that frequently arises has to do with the health of the industrial population as opposed to that of the so-called general population. Since an industrial group is composed of persons who are able to engage in wage-earning activities, it may be assumed that it is physically and mentally a more or less favorably selected group, because the general population includes invalids and persons with physical and mental impairments so serious as to preclude employment. It may be inferred, therefore, that if an industry involves no health hazards of consequence, the sickness rate among its workers should be lower than in the general population.

SICKNESS ABSENTEEISM RATES

With the recognition of the magnitude of nonindustrial sickness and its importance to the industrial and hence to the national economy, there arises the question of *prevention* and *control*. Industrial Hygiene, an activity which has to do with the preservation and protection of the health of the worker, finds itself, therefore, with the problem of determining where, when, and under what conditions ill health is occurring. Thus there is required a measure of sickness for the purpose of making various comparisons, for example, within and among different companies for a particular year, or for a selected period of time.

To take into account all departures from physical or mental health regardless of severity would be a colossal and, at present, an impracticable task since there would be included minor ailments or defects causing discomfort and inefficiency, as well as physical and mental impairments, any of which would not seriously interfere with working capacity. At present, absenteeism from work on account of sickness is the generally accepted measure. The *mortality rate* on the other hand as a sole index of departure from health has long been discarded since it has been shown on several occasions that the pictures resulting from the simultaneous application of a rate of mortality and a rate of sickness to a given population

factors possibly affecting the comparability of rates yielded by the records of industrial sick benefit organizations. There are available the results of a survey of the sick benefit organizations, primarily mutual sick benefit associations and group insurance plans, connected with approximately 700 plants representing over a half-million workers.[3] In 70 per cent of the plants membership in the sick benefit organization was voluntary. In 60 per cent there were no age limits for membership while in those plants with age limits, the lower limit varied from fourteen to twenty-one years while the upper limit varied from thirty-five to seventy years.

Some plants subscribed to certain service requirements. Thus 25 per cent of the plants admitted the employee to membership immediately upon application, the remainder required varying periods of employment before eligibility for membership. A number of plants required a full year's employment.

With regard to the exclusion of employees in certain occupations, 80 per cent of the plants admitted to membership employees in all occupations.

About 30 per cent of all plants either debarred from membership those employees with chronic diseases or admitted such employees to membership with the understanding that no benefits will be paid for those diseases. In some instances an employee's exclusion from membership is left to the discretion of the company or organization.

Of importance also in this connection are the practices with regard to the *notification*, *certification*, and *verification* of disability. In order to draw benefits a disabled member must report his condition to the sick benefit organization. The rule regarding the length of the time interval between onset of disability and its subsequent reporting varied; some plants required a report within twenty-four hours, others within forty-eight hours, and still others stipulated two or more weeks. Practically all plants required an examination by a physician and also that a certificate be submitted to them. Methods for the control of "malingering" were reported by nearly all of the plants; these methods included the services of a visiting committee, a physician or a nurse designated to call upon the disabled member.

forces responsible for disabling sickness are greater in number or intensity in one plant than in the other? A sound conclusion can be formed only if information concerning a number of factors is available. Thus the difference in rate may be primarily accounted for by the presence of a larger proportion of older workers in one plant than in the other, or by a larger proportion of women. For example with regard to age, a plant may yield a sickness absenteeism rate significantly different from the rate found for another plant but when the rates are made specific for age the corresponding rates may be very much alike. Thus the force of morbidity may be of the same magnitude in the two plants but because of differences in the two age distributions of the workers the rates for all ages combined may show a significant difference.

There is a host of other factors of importance in the matter of the comparability of rates particularly those influencing absenteeism data yielded by the records of industrial sick benefit organizations. Among such factors may be listed the following:*

1. Whether membership in the sick benefit organization is compulsory or voluntary.
2. Age limits for membership.
3. Whether or not membership depends upon a certain length of employment.
4. Whether or not certain occupations debar from membership.
5. Whether or not chronic diseases debar from membership.
6. The resources of the benefit organization.
7. Effectiveness of claim supervision.
8. Methods of administration of sick benefits.
9. The average wage of the insured, and the per cent of wages paid in sick benefits.
10. Personal equation of the sick worker.
11. The waiting period. A waiting period at the beginning of disability, usually seven days, stipulates that cases of less than a certain length may not be certified for benefits. Hence such cases are not in the records.
12. Retroactive payment of benefit for the waiting period if the illness produces incapacity of more than a specified period.
13. The period of maximum benefit. Cases of disability are usually closed after a certain number of weeks has elapsed.

Frequency of Factors Affecting Rates.—It is of interest to review the relative frequency of occurrence of some of the

* Compare Kopf, reference 2.

among other things, the existence of the "repeater" or what may be otherwise termed the "sickness-prone" worker. Thus in 1939 among a group of approximately 3000 male workers, 44.8 per cent of the workers had no disabling sicknesses of one day or more recorded for them, 31.5 per cent had one sickness each, 13.0 per cent had two sicknesses, 6.7 per cent had three, 2.5 per cent had four, 0.9 per cent had five, 0.4 per cent had six, 0.1 per cent had seven, and 0.1 per cent had eight.[6]

Another group measured during the six years, 1935–40, revealed that approximately one-half of the male workers and one-fourth of the female workers were not disabled on account of sickness at any time during a year for as long as one day or more.[7] Sixty-five per cent of the male disabilities occurred among workers representing only 21 per cent of those exposed to risk of disability. For the females 63 per cent of the disabilities occurred among 27 per cent of the female workers. In general, increasing age tends to reduce the number of disabilities which one worker may suffer during a particular year, but the average length of each disability tends to increase. Thus, 4.1 per cent of all males under thirty years of age were disabled four or more times during a year while 2.5 per cent of all males fifty years of age and over were disabled the same number of times. The corresponding percentages for the females are 20.6 and 6.0, respectively. Sickness-prone workers, that is workers with four or more disabling sicknesses during one year, were disabled several times the following year.

The Causes of Sickness.—Frequency, disability and severity rates based on a three-year experience of a public utility, 1938–40, are shown by sex and cause in Table 1.[8] Attention is directed to the excesses in the frequency and disability rates shown by the females when compared with the males, the severity rates being generally higher for the males. It will be observed, also, that the respiratory group of diseases is responsible for over half of the absences and over one-third of the days absent. In the respiratory group colds exact the largest toll of absences. While the number of absences is

Reference has been made to the effect on the sickness absenteeism rates of the *waiting* and *maximum benefit* periods. Approximately one per cent of the plants had no waiting period after onset of disability, 60 per cent had a seven-day waiting period and 10 per cent had a seven-day waiting period with payments of benefits retroactive to a specified date. The benefit period per case of disability ranged from three to 104 weeks. Twenty-five per cent of the plants paid benefits for thirteen weeks with a limit of six weeks for cases of pregnancy while 15 per cent paid for twenty-six weeks.

It is obvious from the foregoing that a number of factors, both natural and artificial, must be considered before any conclusions are drawn from the rates. In this connection it was recently stated that the lowest rates were found in plants where the selection of employees is good, where promotion is possible for efficient workers, and where there is stability but not rigidity of organization.[4] Undoubtedly other factors were also involved such as the nagging of a person in charge, a lack of reasonable consideration, and personal mental conflicts.[5]

Conclusions.—The difficulties connected with the drawing of sound conclusions from sickness absenteeism data have perhaps been sufficiently emphasized. Attention, however, should also be directed to the matter of *cause* and the *onset of illness*, both of which may be frequently outside of employment and unrelated to it. Moreover, the diagnosis may be at times equally uncertain.

Because of the importance of the problem of sickness among industrial workers, the difficulties surrounding its investigation should not discourage the collection of data and any attempts that might be made in their analysis. The pertinent data therefore should be uniformly recorded, carefully analyzed, and interpreted with caution.

DISABLING SICKNESS RELATED TO VARIOUS FACTORS

Sickness Proneness.—The sicknesses experienced by a group of industrial workers during a particular period of time are not uniformly distributed among the workers. This indicates,

relatively low for the nonrespiratory-nondigestive group of diseases the corresponding days absent are of a magnitude similar to the days accounted for by the respiratory group, the rheumatic group of diseases being the principal time-loser. The absences for the digestive group and the nonrespiratory-nondigestive group of diseases are similar in number, the outstanding cause under the digestive group being diseases of the stomach, cancer excepted.

Season.—The seasonal variation of sickness from certain causes is well known. The following observations are based on eight-day or longer disabilities. For the respiratory group of diseases the first quarter of the year generally shows the highest frequency rate when compared with the rates for the other quarters. In fact this rate is frequently found to be from twice to three times the rate for the third quarter of the year: in the epidemic year of 1937 the first quarter rate was over four times the corresponding rate for the third quarter.[9] Seasonality was also shown by diseases of the skin, the third quarter frequency rates appearing as peaks in a graph covering all quarters of the ten-year period, 1930–39.[10] A notable seasonal variation was also exhibited by diarrhea and enteritis for the ten-year period, 1932–41, the third quarter rates consistently showing a peak.[11]

Time.—Inquiry into the matter of time-changes in rates of sickness frequently leads to fruitful conclusions particularly with reference to the question of the effectiveness of, or the necessity for, specific control measures. The results of a recent study covering an eighteen-year sickness experience are of interest.[12] This study dealing with the time-changes in the frequency of sickness and nonindustrial injuries causing disability lasting more than one week disclosed the following:

1. All sickness showed a downward trend which was more in evidence among males than among females, the principal determining factor of movement being the respiratory diseases.

2. Nonindustrial injuries showed an upward trend among females as well as males.

3. The trends of the female-to-male ratio rose, those representing the respiratory and nonrespiratory groups almost at the same rate while the nonindustrial injury trend rose more slowly.

4. Among males, diseases of the circulatory system, including diseases of the heart, and appendicitis, showed an upward trend.

TABLE 1.—FREQUENCY OF ABSENCES LASTING ONE DAY OR LONGER DUE TO SICKNESS AND ACCIDENTS, ANNUAL NUMBER OF DAYS OF DISABILITY PER PERSON, AND AVERAGE NUMBER OF DAYS PER ABSENCE, BY CAUSE, EXPERIENCE IN A PUBLIC UTILITY, 1938–40, INC.[1]

Cause (Numbers in parentheses are disease title numbers from the International List of Causes of Death, 1939)	Annual Number of Absences per 1000 Persons		Annual Number of Days per Person		Average Number of Days per Absence		Number of Absences Ending during 1938–40		Number of Days of Disability	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
All Disabilities	927.4	1928.5	8.106	11.737	8.71	6.09	7627	3611	66,663	22,160
Industrial Accidents (169–195)	20.9	4.8	627	015	29.99	9.11	172	9	5,158	85
Nonindustrial Accidents (169–195)	15.5	83.1	491	1.050	10.80	12.62	371	157	1,011	1,982
Sickness	861.0	1810.6	6.988	10.612	8.12	5.78	7081	3175	57,161	20,093
Respiratory Diseases	535.9	992.0	2.821	1.551	5.27	1.61	4407	1851	23,221	8,598
Influenza, grippe (33)	125.1	151.5	867	872	6.92	5.76	1031	286	7,131	1,617
Colds and coryza (101a)	260.5	500.0	731	1.105	2.80	2.81	2112	914	6,007	2,653
Bronchitis, acute and chronic (106)	60.3	87.9	406	560	6.73	6.37	496	166	3,338	1,057
Pneumonia, all forms (107–109)	3.5	3.7	177	181	50.28	49.57	29	7	1,158	317
Diseases of the pharynx and tonsils (115b, 115c)	62.7	176.9	337	1.065	5.36	6.02	516	331	2,767	2,011
Tuberculosis of the respiratory system (13)	9	1.1	162	130	190.71	122.50	7	2	1,335	215
Other respiratory diseases (101b, 105, 110–114)	22.6	60.9	111	338	6.37	5.55	186	115	1,185	638
Digestive Diseases	156.1	333.7	1.222	1.395	7.83	4.18	1281	630	10,051	2,631
Diseases of the teeth and gums (115a, 115d)	17.7	38.7	018	136	2.69	3.52	116	73	393	257
Diseases of the stomach, cancer excepted (117, 118)	83.2	181.8	111	382	5.31	2.07	681	319	3,651	722
Diarrhea, enteritis (120)	31.4	75.2	139	219	4.01	3.31	283	142	1,113	470
Appendicitis (121)	8.8	13.8	297	439	33.92	31.85	72	26	2,142	828
Other digestive diseases (116, 122–129)	12.0	21.2	291	189	21.13	8.93	99	10	2,119	357
Nonrespiratory Nondigestive Diseases	110.9	383.5	2.812	3.901	19.95	10.17	1159	721	23,125	7,366
Infectious and parasitic diseases (1–12, 14–32, 34–44)	10.2	6.1	176	069	17.21	10.83	81	12	1,118	130
Rheumatism, lumbago (58, 59, 156b)	38.5	68.9	528	666	13.70	9.67	317	130	4,343	1,257
Neuralgia, neuritis, sciatica (87b)	11.7	11.3	111	091	12.33	6.56	96	27	1,181	177
Neurasthenia and the like (Part of 84d)	5.2	30.7	108	295	20.56	9.60	43	58	881	557
Other diseases of the nervous system (80–85, 87, except part of 84d and 87b)	1.7	11.1	283	211	59.69	21.67	39	21	2,328	455
Diseases of the eyes and ears (88–89)	12.5	20.7	111	161	8.88	7.95	103	39	915	310
Diseases of the heart and arteries (90–99)	6.2	4.2	392	206	63.27	18.75	51	8	3,227	390
Other diseases of the circulatory system (100–103)	13.1	19.6	216	326	18.38	16.62	110	37	2,022	615
Diseases of the genito-urinary system (133–138, part of 139)	10.7	25.1	360	516	33.60	20.29	88	18	2,957	971
Dysmenorrhea (Part of 139)		135.6		217		1.82		256		166
Diseases of the skin (151–153)	11.5	19.6	163	111	11.26	6.70	119	37	1,310	218
Diseases of the joints (156a)	6.0	5.8	071	189	12.11	12.15	19	11	608	357
All other diseases (45–57, 60–79, 140–150, 155, 157–162)	7.3	21.2	227	757	31.15	35.75	60	10	1,862	1,130
Ill-defined and Unknown Causes (200)	28.1	111.1	110	792	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

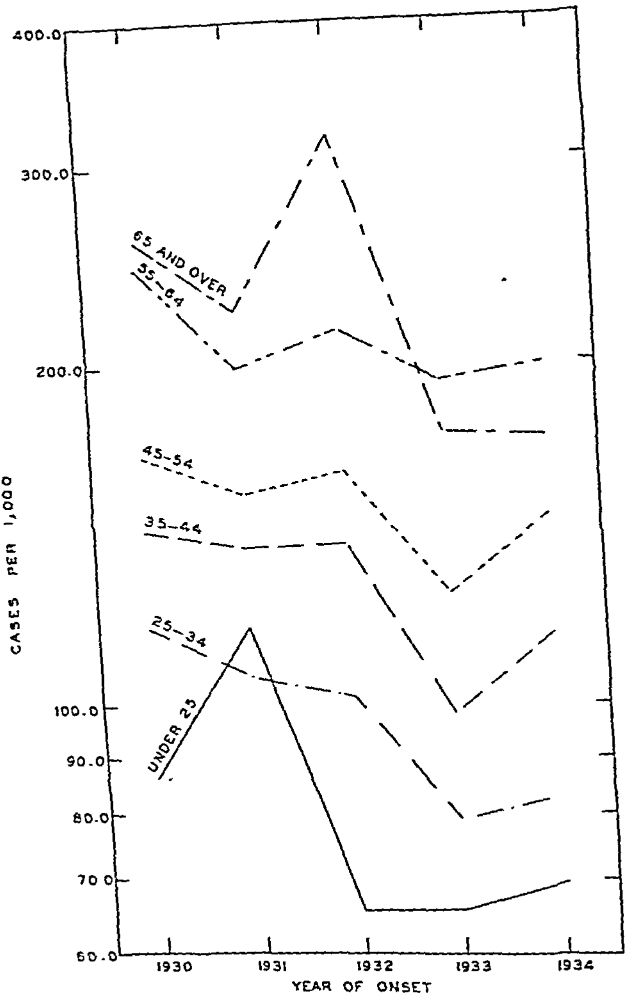

Fig. 159.—Average annual number of cases of disability per 1000 males on account of sickness and nonindustrial injuries, cases lasting eight calendar days or longer, by age group and year of onset of disability; experience of white male members of the sick benefit organization of a railroad, 1930–34, inclusive. (Vertical logarithmic scale.) The graph representing "all ages" is not shown; it follows closely the graph for ages 45–54.

downward trend during a five-year period, the average duration of disabilities moved upward.[15] These observations are presented graphically by age group in Figs. 159 and 160.

5. While not precisely the same, the trends among males were downward for the three industrial groups, iron and steel, public utilities, and miscellaneous industries, in respect of all sickness, respiratory diseases, pneumonia, and respiratory tuberculosis, and upward for diseases of the circulatory system including diseases of the heart.

Occupation.—Some occupations appear to be more associated with certain disabling sicknesses than other occupations. According to a recent report on a sample of glass workers it was found that the number of days of disability because of the rheumatic diseases was over 50 per cent greater than the number accounted for by influenza and grippe.[13] Moreover, grinders, outside workers, and finishers experienced frequency, disability and severity rates well above the average for the entire group of workers.

Color.—There is a notable paucity of published material on disabling sickness among comparable Negro and white populations. Appropriate data covering five years have been made available, the principal results of the analysis of which may be briefly summarized as follows:[14] As the occupations of Negro and white males became more nearly alike, the magnitude of the excess in the frequency rate of disabilities among Negroes tended to decrease, if not to disappear entirely. This suggested that it was differences in the type of work performed together with the associated socio-economic status rather than race *per se* which produced the unfavorable Negro health record when occupation was not held specific. Disregarding occupation, increasing age had the effect of reducing racial differences since the Negro rate showed a tendency to increase less rapidly than the rate for the white workers. The rates for respiratory and rheumatic diseases remained unfavorable for the Negroes and were less subject to the equalizing influence of occupation and age.

Frequency and Duration of Sickness.—It is appropriate to direct attention to the fact that as a measure of economic losses from sickness and injuries, the average frequency rate may lead to erroneous conclusions, since this rate may decline while at the same time the average duration of disability may increase. Thus it was found among a group of approximately 30,000 white male industrial workers that while the average frequency of eight-day or longer disabilities followed a

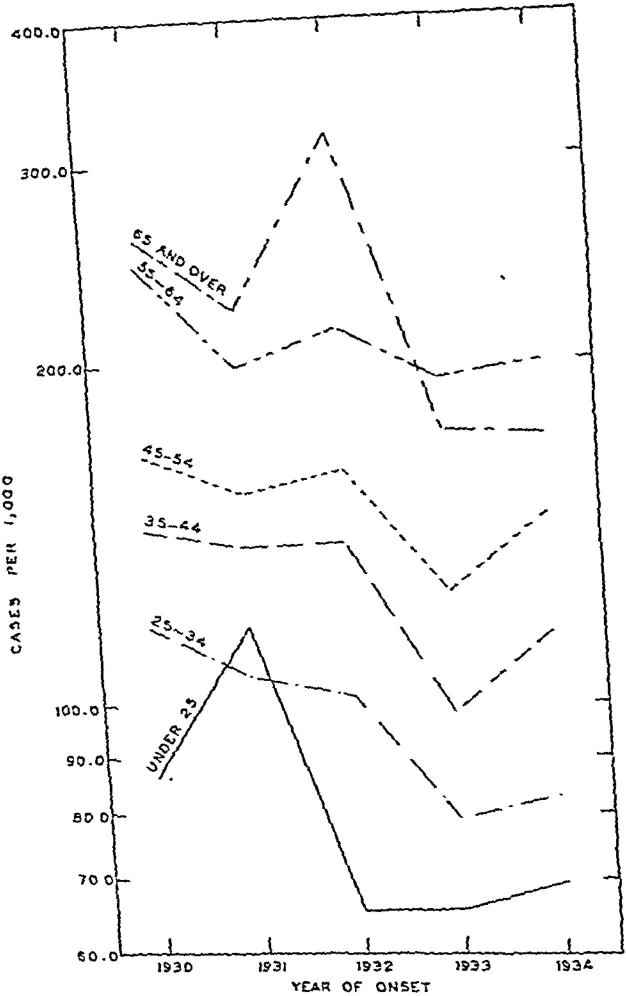

Fig. 159.—Average annual number of cases of disability per 1000 males on account of sickness and nonindustrial injuries, cases lasting eight calendar days or longer, by age group and year of onset of disability; experience of white male members of the sick benefit organization of a railroad, 1930–34, inclusive. (Vertical logarithmic scale.) The graph representing "all ages" is not shown; it follows closely the graph for ages 45–54.

downward trend during a five-year period, the average duration of disabilities moved upward.[15] These observations are presented graphically by age group in Figs. 159 and 160.

It will be seen in Fig. 159 that while for each age group the frequency rates for successive years are not always less than the corresponding rates for years immediately preceding, the time trends of the rates are generally downward. Attention is also directed to the upward trend in frequency with respect to age. This trend for a particular year may be

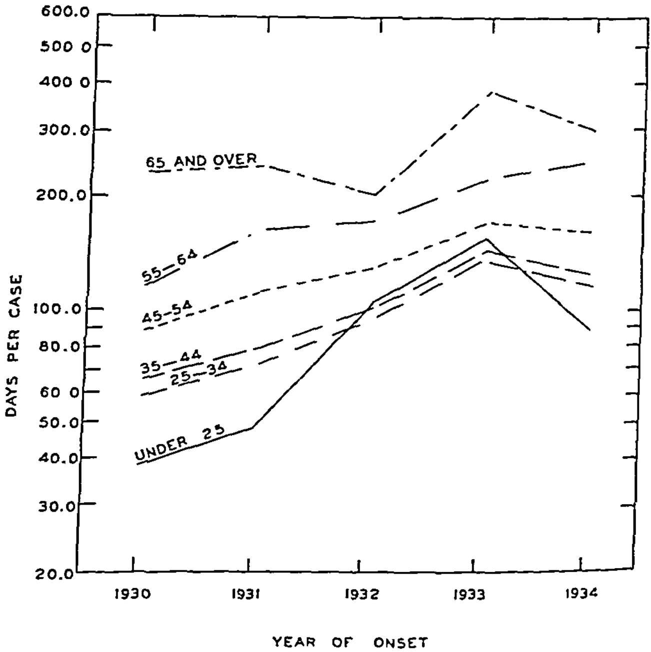

Fig. 160.—Average duration of cases of disability on account of sickness and nonindustrial injuries, cases lasting eight calendar days or longer, by age group and year of onset of disability; experience of white male members of the sick benefit organization of a railroad, 1930–34, inclusive. (Vertical logarithmic scale.) The graph representing "all ages" is not shown; it follows closely the graph for ages 45–54.

seen in Fig. 159 by reading vertically from age group to age group.

Figure 160 shows graphically the movement of the case durations with the passage of time for each of the six age groups. It will be observed that the rates for each age group follow an upward trend. When the age group under twenty-five years is disregarded it is seen that the graphs representing

the time changes of the rates of the remaining five age groups appear in order of increasing age, indicating for each year an increasing duration of case with age. With regard to *rapidity* of increase in the time trends it will be observed that when the youngest and the oldest age groups are disregarded the rate of increase is approximately the same for each of the remaining four age groups; thus while the trends describe different paths, their rate of increase is approximately the same.

The Seven-day Waiting Period.—Since most of the benefit schemes making data available require that seven days elapse between the onset of disability and the commencement of the payment of benefits, such records contain no information on disabilities lasting seven days or less. The question is frequently asked, therefore, about the effect of the introduction of a seven-day waiting period on the frequency of, and time lost from, absences of all durations.

An opportunity to provide an answer to the question presented itself when the requisite data were made available by the record for the five years, 1933–37, of one-day absences or longer that occurred among the employees of a public utility company, one that had been operating under a liberal disability plan for a quarter-century.[18] The analysis of the data showed, among other things, that although the males experienced annually 900 absences per 1000 males, and the females 1820 per 1000 females, only 153 absences among the males and 232 absences among the females extended through the eighth day; in other words, 17 per cent of all recorded absences among the males extended through the eighth day while 13 per cent of all recorded absences among the females extended through the eighth day. Thus if the public utility were to operate under a seven-day waiting period the recorded absences among the males would be reduced by about 83 per cent while among the females the corresponding percentage reduction would be about 87 per cent. Furthermore, of the total recorded days of disability 45 per cent among the males, and 52 per cent among the females occurred during the first seven days of disability after onset.

The Maximum Benefit Period.—While the length of the

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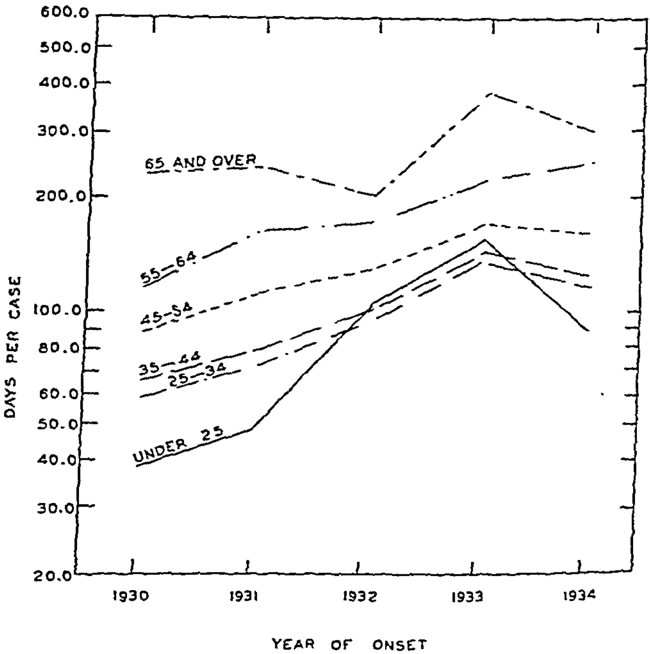

Fig. 160.—Average duration of cases of disability on account of sickness and nonindustrial injuries, cases lasting eight calendar days or longer, by age group and year of onset of disability; experience of white male members of the sick benefit organization of a railroad, 1930–34, inclusive. (Vertical logarithmic scale.) The graph representing "all ages" is not shown; it follows closely the graph for ages 45–54.

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data, therefore, should be uniformly recorded, carefully analyzed, and interpreted with caution.

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maximum benefit period for which benefits are paid does not affect the frequency of recorded absences, it does influence those rates which depend upon time, since the days lost which extend beyond the termination of benefit payments are not in the records. An analysis[19] of the records of some twenty-five benefit schemes showed, among other things, that the extension of a maximum benefit period of thirteen weeks to fifty-two weeks results in an increase of the average annual number of days disabled per male and per female of about 30 per cent and 23 per cent, respectively. An extension from twenty-six weeks to fifty-two weeks, on the other hand, results in an increase of the average annual number of days disabled per male and per female of about 13 per cent and 6 per cent, respectively. These calculations are based on eight-day or longer disabilities with benefit payments retroactive to the first day.

Other Factors.—There are many other factors which are of importance in their relation to disabling sickness. It is appropriate to conclude with the mention of three factors that were emphasized in the reports and memoranda of the British Health of Munition Workers' Committee issued during and after the first World War.[20] Reference is made to *large increases of workers, overtime* with its attendant fatigue, and *night work.* Recent data[21] substantiating the importance of these factors are available only in connection with large increases of workers. Thus it was found that increases in the force of iron and steel workers were associated with increases in the frequency of pneumonia.

SUMMARY AND CONCLUSION

The measurement of departure from the physical or mental health of the industrial worker has been examined. The comparability of rates was discussed. Some of the factors related to disabling sickness were reviewed and the interrelation of a number of these factors was observed. The difficulties involved in the formulation of sound conclusions with reference to the subject of sickness are many, an observation which should not discourage the collection of data and any attempts that might be made in their analysis. The pertinent

data, therefore, should be uniformly recorded, carefully analyzed, and interpreted with caution.

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FATIGUE AND WAR PRODUCTION

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THE PROBLEM OF FATIGUE

THE problem of fatigue in industry has been a troublesome one for many years. During the first World War the need for an inexhaustible supply of war materials greatly aggravated the problem and clearly demonstrated that the wheels of industry were no more efficient than the human factors involved. Excessive sickness and accidents, decreased production, and spoilage of materials called attention to the urgency of this problem and to the need for a careful appraisal of fatigue and its relation to conditions of employment. Consequently, extensive studies were made of fatigue, especially in Great Britain and the United States, and much information has been developed to throw further light upon the subject.†

Fortunately, in recent decades, much progress has been made in combating fatigue, partly by the application of known facts concerning its prevention, and to a large extent by technological progress in many industrial operations. Until our entrance into the present war, the tendency had been growing to shorten the working hours, to select the proper worker for the job, to see that each worker learned to do his job skillfully and efficiently, to mechanize operations previously performed by hand, and to take every precaution to make the working environment as free of health and accident hazards as was practicable.

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† In this paper, no attempt has been made to review the voluminous literature on fatigue or to present detailed findings from the extensive studies on fatigue, both here and abroad. Public Health Bulletin No. 265, by Jones, Flinn, Hammond, and their collaborators, entitled "Fatigue and Hours of Service of Interstate Truck Drivers"[13] contains such a review, as well as other papers cited in the Bibliography.

Now that we have embarked upon another great war that promises to be the most gigantic struggle in history, many of the old problems are arising in an exaggerated form. This is particularly true because of the tremendous increase in the use of mechanized methods of warfare and the urgency of the need for immediate mass production. We have begun to produce airplanes, tanks, guns, ships, and explosives on an unprecedented scale and will continue to increase this production so long as necessary. This will result in longer working hours, speed-up in production, night shifts, the use of unskilled and physically inferior workers, many more women in industry, congestion and delays in transportation, crowded housing conditions in industrial centers, and possibly restriction in the food supplies and other needs of the workers. All these factors tend to cause unusual strain on the workers, contributing toward fatigue and frequently resulting in impaired health. In order to keep those workers efficient and on the job full time, every tool of modern industrial hygiene practice must be utilized as well as known.

DEFINITION OF FATIGUE

Fatigue has been defined in a great many ways by different investigators, as may be seen by reading the numerous reports on the subject. This variation may be ascribed in part to the different lines of attack on the problem, the varying background of the investigators, and the varying causes, both in quality and quantity, of fatigue in the persons under investigation. For example, a biochemical and physiological appraisal of an athlete who has just completed a five-mile race would give a wholly different concept than a psychological study of a student who had been employed continuously at mental work for twenty-four hours. Similarly, the statistically-minded investigator would have a different viewpoint after tabulating and analyzing data on the number of pieces of work turned out by a group of individuals, hour by hour, and day by day, under standard conditions. Other studies have included analyses of accidents, of spoilage of materials, of absenteeism, and of labor turnover as indices of fatigue.

For the sake of simplicity, *industrial fatigue may be*

thought of as a general physiological state manifested by the impaired ability of the worker to do his job properly owing to unfavorable past experience. The objective manifestations of fatigue are often, but not necessarily, accompanied by subjective symptoms.

Causes of Fatigue

This unfavorable experience as the cause of fatigue may have occurred on or off the job, or in both situations. *At work,* it may have included excessive hours of work; excessive speed-up of work; boredom due to repetitive work; awkward work movements; lack of properly spaced rest periods; improper posture; excessive noise; excessive heat; inadequate illumination or glare; noxious dusts, fumes, and gases; inadequate food, water, and salt intake; emotional disturbances caused by fear of not doing the job right or of losing the job; and an improper attitude toward the job.

Off the job factors may have included loss of sleep, intemperance, delays in reaching work, unhealthful living conditions, emotional disturbances about home and family affairs, inadequate nutrition, and illness itself. Of these factors, in recent years *nutrition* has been shown to play an extremely important part in the health and efficiency of the worker. Lack of an adequate intake of vitamins and minerals, in addition to carbohydrate, proteins, and fat, results in a marked reduction of efficiency and well-being. Dissipation likewise compounds the effects of fatigue and interferes with recuperation, thereby forming a vicious cycle. Several of these factors often are working together to produce impaired functioning of the individual.

Fatigue is normally physiological and the worker's full vitality may be quickly restored to normal after an adequate period of rest and sleep. *Repeated excessive fatigue* may lead to a state of exhaustion and the worker's full energies will not be recovered by ordinary means. Such a change may progress gradually and imperceptibly over many months. This morbid type of fatigue, if continued, may, and often does, result in permanent impairment of the worker's health and productive capacity as described by Collier[2] and Walsh.[28] This chronic,

disabling type of fatigue must be especially guarded against in view of the prediction of our leaders that the ability to produce the munitions of war will in the long run determine the outcome.

APPRAISAL OF FATIGUE

Measurement of Productive Capacity.—As there is at present no precise or accurate single method for detecting or measuring fatigue as discussed by Ivy,[12] investigators are restricted in their methods to those measuring impaired functions of the individual or of groups of individuals. One of the most direct methods, of course, when practicable, is to measure the exact productive capacity of workers in relation to their job, decreased productive capacity being considered a manifestation of fatigue. Other factors may be taken into consideration by this method such as errors or spoilage of materials, and accidental injuries.

Appraisal of Altered Functions.—Another approach is to study the individual for evidence of impaired simple functions, either physiological or psychological, and then to try to fit these impaired functions together into a pattern indicating the relative degree of functional efficiency or the fatigue status of the subject. This latter method is the clinical approach discussed by Collier[2] and follows that recently recommended by the Committee on Work in Industry of the National Research Council.[20]

This appraisal of altered functions of the worker is analogous to the diagnosis of a disease whose exact cause and nature are unknown, each altered function being considered as a symptom. Before the discovery of the tubercle bacillus, pulmonary tuberculosis was diagnosed by the cough and blood-tinged sputum, the rales and dullness over the clavicles, the fever and rapid pulse, the wasting, and the common symptoms of toxemia. Similarly, fatigue might be considered to be indicated by a pattern of impaired functions in the individual, including such relatively simple factors as a delayed response to a stimulus, unsteadiness, decreased coordination, impaired muscular ability, changes in blood chemistry, and eye strain, as compared to the normal or rested state. Collier has stated

in this connection that from a clinical or medical standpoint, *only a narrow margin separates fatigue from disease.*[2]

A STUDY OF FATIGUE AMONG TRUCK DRIVERS

A clinical approach to the study of fatigue was recently made by the U. S. Public Health Service through its Industrial Hygiene Division of the National Institute of Health.[13] The Interstate Commerce Commission had requested that a study be made of fatigue with relation to hours of driving and other conditions of work among interstate truck drivers in an effort to adduce further evidence to serve as an aid to judgment in setting a proper limitation on the hours of work in the interest of highway safety. Accordingly a search was made of the available literature and visits were made to other research centers where studies of fatigue were in progress in order to ascertain the most practical methods of attacking the problem. A laboratory for making preliminary tests of methods and equipment was set up at Quantico, Virginia, where U. S. Marine Corps truck drivers were used as subjects. Here drivers were tested both before and after varying periods of driving for evidence of alteration or impairment in many psychological and physiological functions.

It was apparent from the results of these tests that the altered functions observed in truck drivers following a day at the wheel were not the well-recognized physiological changes commonly observed in workers or athletes after severe muscular exertion. Rather they were more of the *psychological type of alteration* as evidenced by tests of psychomotor or neuromuscular function together with some few slight physiological changes.

Accordingly some of these methods were selected for the intensive testing of commercial truck drivers in the field during their actual work day. The methods previously tested and eliminated for this study included treadmill exercise and associated metabolic studies, a refined visual acuity test, a dark adaptation test, an intelligence test, and the majority of biochemical analyses of the blood.

Tests Selected for the Field Study.—The tests selected as of possible value for the field study included a battery of

psychological tests designed to measure simple reaction time, steadiness of hands and body, accuracy of movement, reaction-coordination time, speed of tapping, strength of grip, and the estimation of the size of known objects; an automobile driving test in an apparatus designed to simulate the driving compartment of an automobile; a visual acuity (snap acuity) test; a visual test for measuring critical fusion frequency of flicker; a test of the speed of eye movement (saccadic interval) by means of the ophthalmograph; white blood cell counts and differential counts; biochemical analyses of the blood for serum potassium and total base; and a complete medical history and examination including routine clinical laboratory tests on specimens of blood and urine, and two tests for carbon monoxide in blood. The *medical examinations* were made to appraise the health of this group and to compare it with other industrial groups, to bring clinical data to bear on the problem of fatigue, and to determine if the occupation of truck driving had possibly harmful effects on the drivers' health.

Manner of Testing.—Commercial truck drivers were tested with these selected methods at three field stations. Each driver was given a thorough medical examination and as many of the special tests as possible in the time at his disposal. The men were urged to return a second time to take those tests they had missed on the first visit. In all, 889 drivers were examined in 1200 test sessions. Men were tested in three cities, 229 drivers being tested in Baltimore, 251 drivers in Nashville, and 409 drivers in Chicago.

A complete occupational history was obtained from each man, as well as an accurate account of all his activities during the previous twenty-four hours and the previous week. Tests were given at all times of the day at the end of drives of various lengths. A considerable number of men were tested who had slept since their last drive. Every effort was made to test drivers soon after they had left their trucks if they had been driving or soon after an adequate period of sleep if they had not been driving.

Thus when the field investigation was completed it was possible to analyze and to compare statistically the results of

some 1200 test sessions in groups of drivers with varying driving experience both with relation to a presumably rested state and after periods of more than 18 hours of driving.

Results of This Study of Fatigue

MEDICAL FINDINGS.—The results of the medical examinations indicated that the drivers as a whole were in good health and good physical condition.[13] Two factors contributing to this situation were the youthful age of most of the drivers and the selective nature of the occupation.

By comparing the *weight* of the drivers with the average weight for men of their height and age according to life insurance tables, it was found that while all drivers considered together were of about average weight, the Nashville drivers as a group tended to be underweight, the Baltimore drivers were overweight, and the Chicago drivers occupied an intermediate position.

The *visual acuity* (Snellen) of the drivers was somewhat inferior to that of workers in eight out of nine industries previously reported in the Public Health Service in a statistical survey of the health of 10,000 industrial workers.[1] Normal vision in both eyes was found in the case of 42 per cent of the drivers, while 70 per cent had normal vision in at least one eye. Thirty-nine drivers (4.5 per cent) had visual acuity ratings below the standard set by the Interstate Commerce Commission for pre-employment examinations of commercial drivers (not less than 20–40 in better eye and 20–100 in poorer eye). About one out of ten drivers customarily wore glasses.

Conjunctival injection was the most frequent abnormal physical finding among the drivers. While this disturbance has no known effect on visual acuity and may be due to many causes, it does indicate an unfavorable experience of the eye and was found more frequently in men who had been driving than in rested men.

Few cases of *pulmonary disease* were found among the drivers. There were three cases of bronchial asthma, three cases of chronic bronchitis, and twenty cases of acute bron-

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chitis (associated with colds). No clinical cases of pulmonary tuberculosis were found but no x-ray studies were made.

Heart disease and associated disorders were found in about the same proportion as in other studies made by the Public Health Service of industrial males of similar ages.[13] The function of the heart was not seriously impaired in any of the drivers. A few cases of heart disease were found, however, of such potential gravity that the men affected should not attempt strenuous work.

There was found a rather high incidence of *visible tremor of the outstretched hands* (31 per cent), and of an *increase in knee-jerks or patellar reflexes* (25 per cent). A slight degree of *dermographia* was frequently observed. These findings showed no correlation with hours of driving but did show a slight age trend. They reflect slight disturbances in psychomotor function which may result from a complex variety of causes. *Disorders of speech* and *gait* were rare. Only a few drivers were found with *arthritis* or other disorders causing soreness or stiffness of the joints. With a few exceptions the drivers showed good function of the skeletal system.

No cases of *carbon monoxide poisoning* were found in this study. A few specimens of venous blood from the drivers showed small amounts of carbon monoxide hemoglobin, but not enough to cause symptoms. A few drivers gave a history of previous illness from carbon monoxide, which undoubtedly is a real hazard when the exhaust system of the truck is not working properly.

Syphilis was indicated by the Kahn blood test (4+ or 3+) in nineteen drivers (7.9 per cent) in Nashville, and eighteen drivers (4.6 per cent) in Chicago. Blood tests were not made in Baltimore. *Laboratory tests* including hemoglobin content of the blood, and specific gravity and hydrogen ion concentration of the urine showed no correlation with conditions of work.

Results of Tests.—As a matter of convenience the tests were divided into two groups: (1) *performance* tests which measure the ability of an individual to accomplish a given task, and (2) *nonperformance* tests which measure bodily

states over which the subject has little or no voluntary control. The advantages and disadvantages of these two types of tests have always been the subject of considerable debate among those searching for satisfactory fatigue tests. The advocates of the latter claim that performance tests are so greatly influenced by motivation and the psychological state of the subject that the results are too variable and uncertain to be submitted as rigid, scientific proof. They prefer to depend entirely upon chemical and physiological tests, the results of which cannot be deliberately influenced by the subject.

The advocates of performance tests, on the other hand, point out that most physiological tests such as blood pressure, heart rate, and possibly even blood chemistry, may be decidedly influenced by the emotional state of the subject and so are not really free of psychological influence even though the subject cannot alter his blood pressure or heart rate at will. Certain performance tests have two advantageous features: (1) they directly test functions of basic importance in the efficient performance of specific tasks, such as truck driving, and (2) they are designed to detect relatively slight degrees of fatigue more readily than tests of most of the general physiological functions, many of which are not measurably altered until the stage of exhaustion is approached. Both performance and nonperformance tests were used extensively in the study, as it was felt that neither one alone would give a clear, rounded picture of the symptom-complex known as fatigue.

In the analysis of the results, the drivers were classified according to how long they had driven since sleeping six hours or longer. Those whose periods of driving and sleeping were very much intermixed were omitted from this classification to prevent confusion. Other correlations of the test results were also made such as age trends, sectional differences, and hours of driving during the past twenty-four hours.

Nonperformance Tests.—It was apparent from the history of the drivers that few if any of those tested had recently experienced extreme muscular exertion, such as a football player puts forth in a hard game. In such cases, it is common

to find marked changes in the chemical composition of the blood, a greatly increased white blood cell count, and alterations in the blood pressure and heart rate. No great changes in these functions were found to be associated with hours of driving in the men tested.* Those men who had driven the longest had almost exactly the same potassium and total base concentration in the blood serum, on the average, as the men who had not driven at all since sleeping. If marked changes had occurred in these factors, they would have indicated a fundamental disturbance in bodily function.

The *white cell count* is more sensitive to activity, particularly physical exercise. The men who had driven were found to have higher white cell counts, on the average, than those who had not driven. However, no fine gradations were found by hours of driving. In Chicago, where a definite attempt was made to select those men who had driven long hours and where the largest number of drivers was tested, the men who had driven ten hours or more had higher average white cell counts than those who had driven less than ten hours, but this trend did not appear in the other two cities. The average white cell count of all drivers regardless of driving experience or recent sleep (9948) *exceeded* that usually regarded as normal.

Changes in *heart rate* and *blood pressure* are known to occur as a result of muscular exercise, emotional disturbances, and glandular activities. With increasing hours of driving, the average heart rate was found to be slightly lower. The men who had driven had slightly higher mean systolic and diastolic blood pressures than men who had not driven.

Performance Tests.—As was expected, the performance tests, being much more sensitive to variations in the state of the subject at the time of the test, showed much wider differences between groups of drivers in various conditions. There was no indication of any attempt on the part of the men to influence the results other than to put forth their best effort to make a good showing. Their cooperation, in fact, was excellent. Every subject was treated in exactly the same

* Detailed tabulations showing these data may be found in Public Health Bulletin No. 265.[13]

way in administering any given test and the factor of motivation was thereby held as constant as possible.

The *test of the speed of eye movement*, measured by means of the ophthalmograph, might be considered as intermediate between a performance and nonperformance test. The subjects were instructed to look, without moving the head, first at a lighted point to the right and then at a lighted point to the left, as these were alternately illuminated. This was repeated a number of times. While the change of fixation involves a voluntary act, the actual speed of movement of the eye, of which measurements were made, is considered to be involuntary. The results were similar to those of the nonperformance tests already discussed. The men who had driven had a slower mean speed of eye movement than those who had not driven since a major sleep, but there was little difference between those who had driven a long time and those who had not been driving so long.

Appreciation of the speed at which a flickering light appears to fuse into a steady light* is involuntary in one sense of the word, but the measurement depends upon the subject's judgment. If a subject repeats the test several times in succession he reproduces his original results very closely. This illustrates the fact that tests which are dependent upon a subjective response do not necessarily give variable readings. The results were consistent in all three cities, showing that the average rate of flicker at which fusion occurred was higher for the group of men who had not driven at all as compared to those who had driven one to 9.9 hours, and decreased to the lowest point in the case of those who had driven ten or more hours since sleep.

The *driving test apparatus* was designed to simulate the driving compartment of a motor vehicle. The subject was seated behind a steering wheel and instructed to keep the hood of a miniature automobile, operated by the steering gear, in the middle of a moving road scene. When a traffic

* The subject is shown a flickering light of fixed intensity produced by rotating a serrated disk between a light source and the eye of the observer. In the test the rate of rotation is determined at which the sensation of flicker disappears and the light appears to become steady, the so-called *flicker-fusion point*.

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made in the first five seconds, middle five seconds, last five seconds, and for the total forty-five seconds were recorded. The results are best interpreted when expressed in terms of work decrement. Subjects who had driven a long time did well during the first five seconds, were poorer in the middle five seconds, and became still poorer in the last five seconds. On the other hand, rested subjects showed poorer performance on the middle five than on the first five seconds, but showed improvement during the last five seconds.

The simple reaction time test measured the time required for a subject to press a button with his finger at a given signal. The reaction-coordination time test measured the time required for the subject to move a pencil from one hole and place it in another hole; and the manual steadiness test measured the ability of a subject to hold a metal stylus in a series of small holes in a brass plate without touching the sides of the holes. On each of these tests the average performance decreased with increasing hours of driving.

It therefore appears that if one defines fatigue as an altered psychophysiological pattern, the type and degree of fatigue produced by truck driving, up to quite long hours, were most strikingly revealed by changes in the relatively simple motor functions measured by these four tests. All four of these tests can be administered in a short time with easily portable apparatus.

As some individuals performed better on some tests and worse on others, it is very difficult to compare the *general status* or fatigue pattern of individuals or groups of individuals in such cases. Therefore, a method was devised for assigning a *single, composite score* to each driver[13] which averaged his relative deviation on several tests from the average scores of the rested group on the same tests. Composite curves, made possible by this method, showed that the drivers' average functional efficiency decreased progressively with increasing hours of driving, not only on the four tests previously described but on all of the thirteen functions that showed changes with hours of driving. In comparing individual drivers, it was found that by setting an arbitrary level of low functional efficiency, only 9 per cent of the men in the

light beside the road changed from green to red, the subject put his foot on the brake pedal as rapidly as possible. Several variations of the test were used, but in the one which showed the most consistent results, the percentage of the time the subject kept his car on the road and the length of time required to put his foot on the brake when the light turned red, were both recorded.

It is apparent that this test, which is designed to duplicate actual driving experience so far as possible in the laboratory, is at a fairly high level of complexity and would therefore give rather variable results. Such was found to be the case. The two tasks of steering and braking competed for the attention of the subjects, some of whom were relatively efficient in steering but slow in reaction, while the reverse was true in others. Nevertheless, when scores were computed from the combination of steering efficiency and reaction time, men who had not been driving since sleep had the best average score, men who had been driving from one to 9.9 hours had a poorer average score, and men who had been driving ten or more hours since sleep were the poorest of all.

In *accuracy of aiming*, the men who had driven were somewhat less efficient than those who had not driven since sleep, but the results were variable, and showed no consistent trends with hours of driving. The *strength of grip*, as tested by the dynamometer, was a trifle greater in men who had driven than those who had not driven.

The four functions which showed the closest relation with hours of driving were: *speed of tapping*, *simple reaction time*, *reaction-coordination time*, and *manual steadiness*. On all four of these tests, the men who had not driven since sleep performed with the greatest average efficiency, the men who had driven one to 9.9 hours were less efficient, and the men who had driven ten hours or more were least efficient of all. The same was true of a fifth function, *static equilibrium* (body sway) which, however, was tested in only one city.

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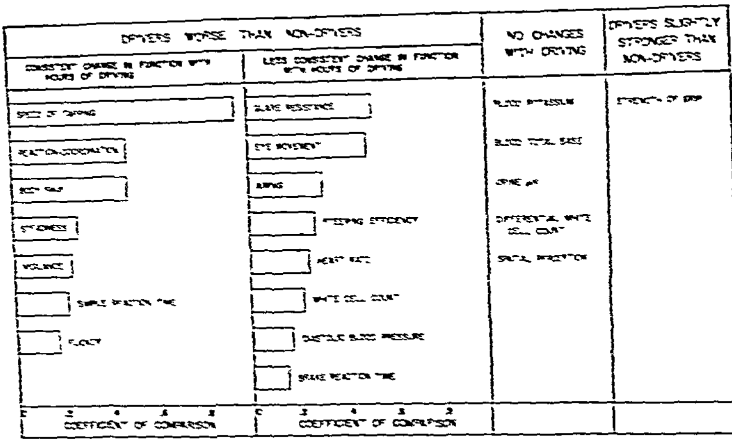


Fig. 161.—A list of the functions tested classified by the consistency of the changes found with hours of driving. The lengths of the bars indicate the relative difference between the mean scores of the men who had driven and those who had not driven since major sleep. This graph is a general summary only, full details being presented in Public Health Bulletin 265.[15]

causing a diminished capacity for continuing that occupation until the worker is allowed a period of rest for recovery.

Individual Human Factor in Fatigue

No critical point was found in the hours of driving scale in which there was such a sudden change in functional efficiency as to give an obvious figure for the limitation of hours of driving. Such a point could not be expected in view of known individual variation in all biological phenomena. Hence there is a great variation in the individual's ability to compensate for fatigue, in his resistance to deleterious influences, and in his recovery state at the beginning of work. Short of exhaustion, it cannot be expected that there is a dividing line, on one side of which a person is wholly efficient and on the other side wholly inefficient, taking into consideration the complexity of the fatigue pattern for the whole organism, and its gradual alteration. This is true of groups of workers as well as for the individual worker with the added

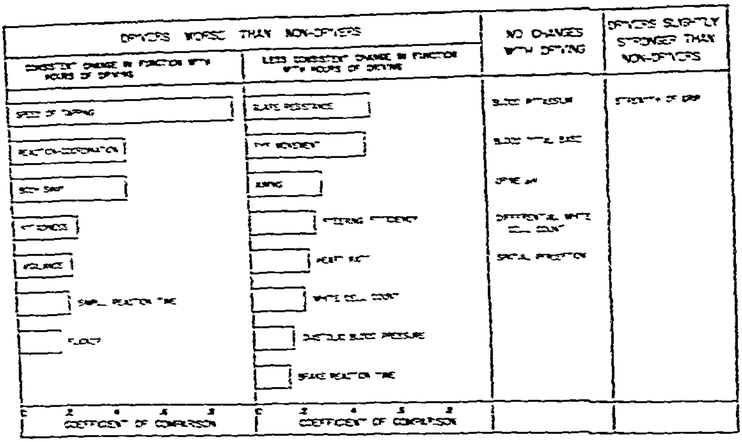
rested group fell below this level as compared with 27 per cent, 33 per cent, and 42 per cent of the men in the 1 to 7, 8 to 11, and 12+ hours of driving groups, respectively. It was found that the physician's independent judgment of *apparent fatigue* and the driver's own estimate of fatigue correlated well with the composite scores assigned the individuals in all driving groups, thereby substantiating the validity of this method. For various reasons, some drivers showed evidence of fatigue even in the presumably rested group, attributable to outside influences largely. It was believed that the differences demonstrated between the driving groups and rested group would have been greater but for this factor.

Conclusion.—After discussing these considerations, the authors concluded: While many factors in the daily lives and background of the drivers may operate to reduce the efficiency, and, therefore, the safety of driving, long hours of driving have been shown to be important in this respect. Furthermore, hours of driving are controllable while many of the other factors are not readily controlled except by the drivers themselves. It would therefore appear that a reasonable limitation of the hours of service would, at the very least, reduce the number of drivers on the road with very low functional efficiency. This, it might reasonably be inferred, would act in the interest of highway safety.

DISCUSSION

It is apparent from the results of the foregoing study that *a pattern of psychological and physiological changes* was established indicating impaired functional efficiency in relatively simple functions that are involved at a high level of complexity in the act of driving. This impaired functioning of the driver was roughly proportional to the number of hours spent at the wheel since his last period of sleep. This pattern can be interpreted as the syndrome of truck driver's fatigue, so far as tested, as shown in Fig. 161. Doubtless many other functions are involved that are of importance in appraising the behavior of the whole organism. In many other occupations the pattern of fatigue would be different as in bricklaying, blast furnace tending, or fuse assembling. In each

instance, however, one would expect the impairment of certain functions primarily concerned with the occupation.



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complexity of the variations in different jobs. Differences in attitude and motivation have been shown also to play a large part in maintaining efficiency.[22]

Nevertheless, as functional efficiency decreases progressively with increasing hours of driving and in other work as well, it is apparent that a reasonable limitation of such hours would decrease the number of unfit workers and the possibility of the ill effects due to excessive fatigue. The exact number of hours of work must necessarily be an administrative decision in which the urgency of the task and need of immediate high production must be balanced against the risk of lowered production in the long run if the human machine is pushed too far.

Length of the Work Week in War

In a vital emergency of short duration, a great increase in both hours and speed of work will increase production proportionally since most workers will be able to compensate to this situation for a time. In a prolonged war, however, such a productive spurt would be wasteful in that as chronic fatigue is induced among the workers, there would be increasing illness and injuries, and decreasing quantity and quality of production. It would seem desirable, then, to bend every effort to determine the *optimum hours of work* for maximum and prolonged production in our national emergency. It is to be expected that this level would vary from one industry to another and that considerable study as well as trial and error will be necessary to reach an efficient balance.

British Experience.—The British experience devolving from researches into industrial fatigue and efficiency have been outlined in a recent publication by H. M. Vernon.[27] He points out that the cardinal error committed by many employers of labor during the last war was the imposition of excessive hours of work. Employees who had been working from forty-eight to fifty-four hours a week were required to work seventy, eighty, and even ninety hours a week in an effort to increase the production of war materials. With these excessive hours of work, investigations showed that because of increasing sickness, accidents, and spoilage of materials,

production suffered heavily. *Illness* was found to be the cause of twice as much lost time among both men and women who worked long hours as among those who worked relatively short hours.

It must be borne in mind that there were variations in living and working conditions between the English workers of 1914–18, and American workers of the present time, including previous customary hours of work, restrictions of diet, and in the working environment. It is a matter of conjecture, therefore, as to exactly how far these findings apply to the present situation in America.

Kossoris, in summarizing the British investigations,[16] showed that men engaged in the heavy manual labor of sizing fuse bodies increased their total weekly production 22 per cent when the weekly hours of work were decreased from 66.7 to 56.6 (15 per cent), these results being obtained over a thirteen-month period. This was attributable to a 39 per cent increase in hourly output and a decrease in wasted time from 8.5 hours per week to 5.3 hours. It was also shown in a ninety-three weeks' study of 100 experienced female operators on capstan lathes, turning aluminum fuse bodies, that by reducing the weekly hours in the plant from 74.5 to 63.5 there was no decrease in production, and that when the hours of work were further reduced to 55.3 there was a 13 per cent weekly increase in production.

The possible improvement in output during a shorter work week was found to depend largely on the amount of control the workers had over the speed of production, the improvement being greatest when operations were entirely performed by hand, but improvements in production were found even in operations largely governed by the speed of the machines after reducing excessively long hours of work.

As regards *most suitable maximum hours* of work with regard to British experience in the past and present war, Vernon suggests that hours for women be limited somewhere between forty-eight and fifty-four hours a week, and consideration be given to holding to the forty-eight-hour level.[27] Young girls of sixteen and seventeen should not be required to work more than forty-eight hours a week. For labor re-

quiring a similar degree of physical effort, he states that men can undoubtedly work longer hours than women, and skilled men such as tool makers and tool setters, whose work is comparatively light physically, can work sixty hours a week without undue fatigue, and probably rather more. For heavy physical work, however, he suggests the work week be limited to forty-eight hours.

It should be remembered that in many recently expanded defense areas it takes our workers an hour or more each way to go to and from work, thus effectively adding as much as fourteen hours to their work week. In some instances, this time required for commuting may be as deleterious to the worker's efficiency as additional hours on the job.

Rest Pauses.—Vernon also reports that the instituting of short rest pauses during the middle of the morning and afternoon work periods had a tendency to increase production despite the actual time lost. In one investigation there was a 6.2 per cent increase in production from a seven- to ten-minute pause in the work during the morning. The beneficial effects of these rest pauses seemed enhanced by serving light refreshments. This practice is particularly valuable in monotonous, repetitive work. These findings were also confirmed in a five years' study in the Western Electric Company's plant at Hawthorne.[18, 22] Hamilton has discussed the value of rest pauses and other factors in producing a good attitude among the workers and in preventing fatigue.[8]

Importance of Nutrition

Adequate nutrition is of particular importance in preventing excessive fatigue and in maintaining the workers' health. Sebrell[24] points out that as more and more clinical studies are being conducted, we are learning that deficient diets—short of producing the symptoms of a full-blown deficiency disease—may be responsible for such symptoms as mental depression, indigestion, easy fatigue, loss of weight, retarded learning ability, and interference with vision. He quotes the recommendations proposed by the Committee on Food and Nutrition of the National Research Council showing that much more food, including vitamins, is needed by active men

and women than by inactive persons, and states that at present we have thousands of workers under greater strain and activity than they have had for years, with no organized effort to improve their food supply. Many have also moved into new sections not prepared either to feed or to house them properly, in many instances causing their nutritive status to become worse.

Obviously, industrial medical services as well as plant officials should utilize every possibility to see that the workers know the fundamentals of an adequate diet, and that inexpensive well-balanced meals are available at the plant cafeteria. Likewise, a *progressive program of nutritional education* should be an integral part of every health department's activities.

Proper Handling of Personnel

Finally, a well rounded out personnel policy providing for the social and economic welfare of the workers pays large dividends. Ivy[12] has remarked in speaking of moderate work that many things have been found to impair and to improve productivity in factories, and that it appears as if most anything the management does, which attracts the interest of the workers or indicates interest in their welfare, improves productivity. It has been repeatedly demonstrated that a favorable attitude of the worker toward his job and the employer helps to prevent fatigue and increase production.

RECOMMENDATIONS

Taking into consideration all the information available on fatigue and its prevention, Surgeon General Thomas Parran of the United States Public Health Service recently made the following statement on the Workers' Health and the Twenty-four-hour Schedule:

"As in the first World War American industry is faced with the problem of 24-hour-day, 7-day-week operation. Fatigue is a health hazard and a hazard to continuous production. The addition of second and third shifts to plant schedules necessitates the establishment of the rotating shift.

"To maintain workers' health and thereby peak production, industries operating on the 24-hour basis must take special precautionary measures to minimize the effects of night work and the rotating shift. The United States Public Health Service makes these recommendations:

"1. Workers changing over from day to night shift every 2 or 3 *weeks* find it difficult to adjust their eating and sleeping habits. In plants operating on a 24-hour schedule, shifts should not be rotated more often than every 2 or 3 *months*.

"2. Each nursing shift should rotate at the same time as the workers' shift, so that the same nurses will always be acquainted with the workers they are treating.

"3. Women with home responsibilities often try to do their housework during the day while working on night shifts. Chronic fatigue in short order is the result. In general, women workers who also have domestic duties should not be employed on the night shift.

"4. A 60-hour week—on a 10-hour day, 6-day week basis—may become necessary. Excessive increases in working hours lead to reduced efficiency during working hours, absenteeism and sickness. A 48-hour week—on an 8-hour day, 6-day week basis—is preferable. Individual workers should have one day in every 7 days reserved for rest and recreation; this does not preclude continuous operation of the factory.

"5. Organized rest periods help maintain production at a high level. Five to fifteen-minute rest periods should be provided at the end of the first quarter, and again at the three-quarter mark of each shift. This is especially important in repetitive monotonous work or heavy manual labor. Milk, soft drinks, sandwiches and candy should be available during the rest periods.

"6. A particularly high standard of lighting is necessary in plants operating at night or under blackout conditions. Proper lighting reduces fatigue, improves morale, and prevents accidents due to poor light or glare.

"This six-point program should be based on the broader industrial hygiene service advocated by the United States Public Health Service which includes:

"Medical and nursing services available to workers on each shift; good plant housekeeping; adequate sanitary facilities; adequate ventilation; control of exposures to hazardous operations or to noxious dust, fumes and gases; proper placement of workers in jobs for which they are physically and temperamentally suited; reduction of excessive noise (a well-known fatigue producer); health and safety education programs, such as teaching proper posture on the job, sanitation, nutrition, and mental hygiene; paid vacations of at least one or two weeks a year."

Role of Industrial and Family Physicians

The medical profession plays a most important role in increasing war production by maintaining and improving the workers' health. The *industrial physician* through his daily contacts with workers, his frequent inspections of the plant and observation of workers at their job, his study and analysis of sickness and accident data, and his general knowledge of

the workers' problems is in a strategic position to detect and help control unfavorable conditions in the plant that are causing undue fatigue, as well as other detrimental factors in the working environment. In his capacity as the plant's health officer he is able to help coordinate the activities of the medical department, the safety department, the welfare division, plant officials, private physicians, and local health departments in bettering the health and efficiency of the workers. He should supervise and educate the workers on nutritional problems. As inadequate food intake is an important cause of fatigue and illness, especial care must be taken to insure an adequate supply of food to these workers. It is vital for men at heavy manual labor to receive an adequate supply of carbohydrates and fats, even if it becomes necessary to place restrictions on the general population.

Family physicians caring for industrial workers should be increasingly alert to detect illness or other harmful effects of the patient's occupation on his health, and consult with the plant physician or officials regarding the prevention of such illness. Most of the highly industrialized states now have official industrial hygiene units to give technical and advisory services on industrial health problems.

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PREVENTION OF ILL HEALTH IN INDUSTRY

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ILL HEALTH DUE TO EXPOSURE TO HARMFUL CHEMICALS

CONTINUOUS, efficient, productive employment of every worker in the United States, and especially of those in war industries, calls for a practical plan of preventive medicine, which can be applied to all situations in which workers may be exposed to harmful chemicals.

We must not forget the lessons of World War I. In allied as well as enemy countries of Europe, ignorance of the physiological action of many of the then limited number of synthetic chemicals needed in war matériel, caused ill health on a scale which greatly hampered production. Since 1916, the United States has become a leader in chemical industry. The use of organic chemicals has been extended until practically no war manufacture can completely dispense with materials capable, if carelessly used, of injuring health. The rush of mass wartime output, at a time when the armed forces need large numbers of young physicians, leaves too few men trained in industrial medicine. It grants too little time to train men and too little time, also, in which to collect, by the usual rather slow methods of research, detailed information on the many potentially harmful substances to which thousands of new workers may be exposed. This situation calls for a simple presentation of fundamental facts which can be used at once in a medical program of health conservation.

Premises Upon Which Work Must Be Based.—In presenting such facts, two major premises must be remembered. *First*, the duty of medicine in industry is to prevent ill health, not merely to diagnose injury already produced. *Second*, any chemical, however potentially harmful, can be made and used

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adequate human data have been collected: These two different lines of attack lead to the same qualitative and quantitative results.

Initial Reactions of Organisms to Chemicals

The initial reactions of living, intact, human and animal organisms to foreign chemicals which, when introduced into the body, may have a systemic (as opposed to a purely local) action, are the same no matter what the structure or physical properties of the chemical. They are the same no matter what the route of absorption of the material. Since it is very difficult to control absorption of foreign substances through the skin, the quantitative studies in our research have been made by inhalation experiments. When the tissues are presented with sufficient concentrations of foreign chemicals to cause a minimal reaction, that reaction is one of *stimulation*. This leads, among other changes, to an increase in the tonus of blood vessel musculature, and to a similar trend in the activity of those portions of the heart structure which produce heart sounds. (We deliberately refrain from speaking of "tonus" of heart muscle, since physiologists, in general, hold that there is no proof of the existence of such a condition. However, our study of heart sounds certainly indicates that cardiac muscle has properties analogous to that which, in other muscles, is included in the term, "tonus.") This stimulation can be demonstrated as a trend of blood pressure, and especially diastolic pressure, toward or beyond the limits of normal range, or as a change in the pitch of heart sounds or in the "damping" of these sounds. At the same time, there may appear a limited group of symptoms, which includes:

Increased fatigue (almost universal)
Headache
Gastro-enteric abnormality (nausea, loss of appetite, a feeling of fulness in the stomach, pain in the epigastrium, etc.)
Dizziness
Precordial pain

Increase in the concentration of foreign chemical in the tissues changes stimulation to *depression*. The tonus of blood vessel muscles decreases, with a consequent fall in diastolic

with minimal hazard to health if care, proper information, and ordinary common sense are available. Conversely, the absence of care, proper information and common sense may lead to ill health in the use even of relatively harmless substances.

A program of preventive medicine cannot be based on branches of medical science used in diagnosing disease. It must rest upon *physiology*, which defines the usual (*i.e.*, the "normal"), and allows detection of the least departure from that usual. The program cannot be based upon data which describes either lethal or highly injurious dosage as determined in experimental animals. It must rely upon facts which are so general that they apply to at least a majority of chemicals now in use or which may come into use. These facts cannot be deduced from chemical structure or physical properties of materials, new or old, for no general formula exists which makes such deduction possible.

Several years' study of this aspect of industrial medicine shows that a general preventive medical program can be set up if one considers, not the individual nature of many chemicals, but rather the *first reactions* of all living tissue to foreign materials. Of these first reactions, only those can be used in that program which can be measured with simple apparatus in minimal time. Reactions which cannot be simply defined or measured, and which, therefore, become matters of opinion, are of little direct value.

Methods of Study.—Two general methods of research have been used in this study. The first, *measurement of blood pressures*, has been described in a recent paper by Foulger and Fleming.[1] The second, as yet unpublished, was devised because of interesting blood pressure changes found in early exposure to chemicals. It is based on *measurements of changes in pitch or in the "damping" of heart sounds.* As initially developed on experimental animals, it required rather complicated audio-frequency analysers and sound recording apparatus. Recently, it has been found possible to make these sound measurements with relatively simple, standard equipment, which could be available in any industrial medical unit. The details of this new procedure will be published as soon as

work it is found that the ratio of the number of abnormal blood pressure scores to the expected number gives a figure which is directly related to the concentration of the toxic

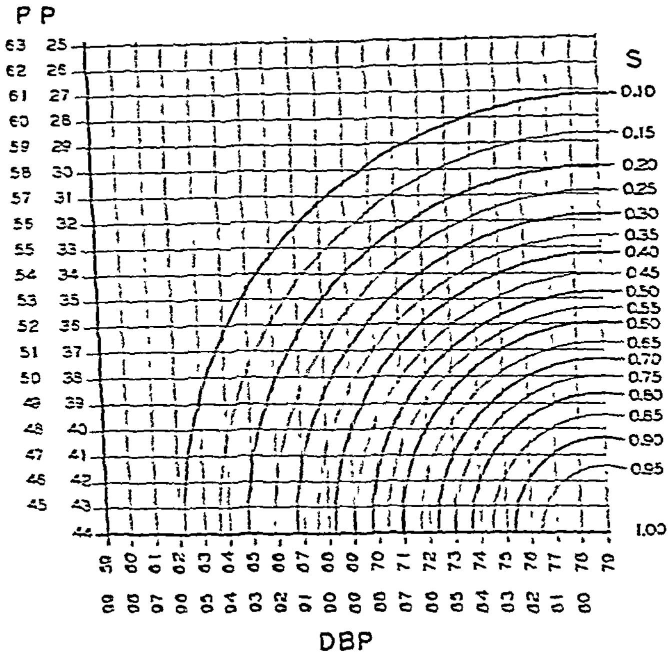

Fig. 16[illegible].—Nomograph for calculation of diastolic pressure and pulse pressure score. Read diastolic blood pressure along horizontal line marked "DBP," and pulse pressure along vertical line marked "P P." From diastolic blood pressure reading, trace vertically to meet horizontal drawn from pulse intersection. Read score at right hand edge of circle, under "S." For greater accuracy, estimate relative distance from two quadrants between which intersection of pulse pressure and diastolic blood pressure readings lie.

Example: Blood pressure reading, 129/82. Pulse pressure, 47. Intersection of diastolic blood pressure, 82, and pulse pressure reading, 47, lies between quadrants marked 0.85 and 0.90, somewhat nearer to quadrant 0.85. Score to nearest degree of accuracy, 0.87.

material in the atmosphere inhaled by the animals. In clinical studies of workers, this ratio of observed to expected abnormal blood pressure scores is a valuable index of the status of individuals or groups.

pressure (or both diastolic and systolic pressure) toward or below normal limits. At the same time there is further change in the pitch and "damping" of heart sounds. At this stage, the symptom group becomes more obvious and frequent, especially fatigue and gastro-enteric abnormality. There may also be a tendency to circulatory collapse when changing posture.

Blood Pressure Scoring System

At the moment, the best means of detecting and following these early results of exposure to chemicals is the frequent measurement of systolic and diastolic blood pressure, by standard methods, and the conversion of the blood pressure readings into a "score," which indicates the trend away from or toward normal limits. The method of scoring outlined in the paper cited[1] above is based upon the difference between recorded pulse pressures and diastolic blood pressures and respective established mean values. The further these pressure components deviate from the means, the lower is the "score." This score is expressed in decimal fractions, with a maximum value of 1.0 when both pulse pressure and diastolic pressure lie simultaneously at the established means. The trend of value of the scores is a useful index of the trend of effect of exposure. Scores between 0.1 and 0.2 are considered as of doubtful normality, and scores of 0.1 or less are definitely abnormal. The frequency of occurrence of definitely abnormal scores is compared with the expected frequency in a normal population of the same size, using the mathematics of random sampling and taking, as a yardstick, an expected 6 per cent abnormal scores occurring by chance alone in a very large population of normal persons.

A simple graph (Fig. 162) makes it easy to calculate the blood pressure score from pulse pressure and diastolic blood pressure. Table I is used in comparison of the observed number of abnormal scores in a group of examinations with the number expected by chance alone in a normal group of the same size. This chart gives to the nearest whole number, the maximum number of examinations with scores of 0.1 or less which would be expected to occur by chance alone, in groups of one to 600 examinations of normal workers. In animal

First, two points must be emphasized. (1) The blood pressure scoring method reaches its greatest value only when workers under study have been selected for their jobs by a *pre-employment examination* which demands a normal blood pressure score. This is not a drawback, for no preventive medical program will be effective in the absence of proper medical selection of workers according to the nature of their future work. (2) Many people are not accustomed to thorough medical examination, and their first such experience appears to them almost as a personal affront. The sudden, unexplained introduction of a routine medical examination program, even if it only requires readings of blood pressure, can cause apprehension. Quite a number of workers may show a purely *psychic reaction* with a rise in systolic blood pressure, without a corresponding change in diastolic pressure. The resulting high pulse pressure often gives an abnormal blood pressure score. This psychic reaction is well known and, indeed, is suggested by Armstrong[2] as a means of detecting personalities unsuited for military aviation. In industrial practice, this reaction on first examination should not be considered abnormal, unless the worker is to make or use chemicals which cause psychic abnormality, or unless his future work requires a highly stable personality of the type needed in military aviation. But the *recurrence*, during a program of frequent examinations, of a pulse pressure high enough to give an abnormal blood pressure score, when not accompanied by abnormal diastolic pressure, indicates unusual instability and its source should be sought.

Stages of Change in Blood Pressure.—When blood pressure scores or changes in heart sounds are followed carefully in animals or workers continuously exposed to low concentrations of chemicals, the trend of events can be described as five, fairly distinct stages. These are:

Stage 1: The minimal concentration of a harmful chemical, adequate to cause the initial stimulation, can be withstood for a varying period of time without the appearance of symptoms or of significant trends in blood pressure score or in the frequency or "damping" of heart sounds.

Stage 2: If this low grade exposure is continued, there will come, sooner or later, a point at which there is a perceptible difference between

TABLE 1

MAXIMUM NUMBER OF ABNORMAL EXAMINATIONS EXPECTED BY CHANCE ALONE IN EXAMINATION GROUPS BETWEEN 1 AND 600 EXAMINATIONS

Total Exams.	0	5	Total Exams.	0	5	Total Exams.	0	5
	Max. Ab. Expected			Max. Ab. Expected			Max. Ab. Expected	
1	1	1	200	19	19	400	33	34
10	2	3	10	19	20	10	34	34
20	3	4	20	20	21	20	35	35
30	4	5	30	21	21	30	36	36
40	5	6	40	22	22	40	36	37
50	6	7	50	22	23	50	37	37
60	7	8	60	23	24	60	38	38
70	8	9	70	24	24	70	38	39
80	9	9	80	25	25	80	39	39
90	10	10	90	25	26	90	40	40
100	11	11	300	26	26	500	40	41
10	12	12	10	27	27	10	41	42
20	12	13	20	28	28	20	42	42
30	13	14	30	28	29	30	43	43
40	14	14	40	29	29	40	43	44
50	15	15	50	30	30	50	44	44
60	16	16	60	30	31	60	45	45
70	16	17	70	31	32	70	45	46
80	17	17	80	32	32	80	46	46
90	18	18	90	33	33	90	47	47
						600	47	

To obtain plant or group score:
Count (A) Total number of examinations;
(B) Number of examinations with Pulse Pressure-Diastolic Pressure Score 0.10 or less;
Divide (B) by value of Max. Ab. Expected, given in table.
Score above 1.00 indicates too many abnormal examinations.

This method of study has proved successful in deciding the condition of workers wherever chemical exposure is expected, and in following both the trend of results of that exposure and the effect of changes in physical means of protection such as ventilation.

DISCLOSURES OF THE BLOOD PRESSURE SCORING SYSTEM.—Since the method of use of the blood pressure scoring system has already been described in an easily available publication, the present paper will be confined to important general facts disclosed by using that scheme in studying many thousands of examination records of workers handling a wide variety of chemicals.

First, two points must be emphasized. (1) The blood pressure scoring method reaches its greatest value only when workers under study have been selected for their jobs by a *pre-employment examination* which demands a normal blood pressure score. This is not a drawback, for no preventive medical program will be effective in the absence of proper medical selection of workers according to the nature of their future work. (2) Many people are not accustomed to thorough medical examination, and their first such experience appears to them almost as a personal affront. The sudden, unexplained introduction of a routine medical examination program, even if it only requires readings of blood pressure, can cause apprehension. Quite a number of workers may show a purely *psychic reaction* with a rise in systolic blood pressure, without a corresponding change in diastolic pressure. The resulting high pulse pressure often gives an abnormal blood pressure score. This psychic reaction is well known and, indeed, is suggested by Armstrong[2] as a means of detecting personalities unsuited for military aviation. In industrial practice, this reaction on first examination should not be considered abnormal, unless the worker is to make or use chemicals which cause psychic abnormality, or unless his future work requires a highly stable personality of the type needed in military aviation. But the *recurrence*, during a program of frequent examinations, of a pulse pressure high enough to give an abnormal blood pressure score, when not accompanied by abnormal diastolic pressure, indicates unusual instability and its source should be sought.

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Stage 1: The minimal concentration of a harmful chemical, adequate to cause the initial stimulation, can be withstood for a varying period of time without the appearance of symptoms or of significant trends in blood pressure score or in the frequency or "damping" of heart sounds.

Stage 2: If this low grade exposure is continued, there will come, sooner or later, a point at which there is a perceptible difference between

the normality of blood pressure scores at the beginning of the week of work and those at the end of the week. But a weekend of proper rest will allow complete return to normal.

Stage 3: After stage 2 comes a period during which there is a perceptible difference between morning and afternoon blood pressure scores on each work day. However, at this stage, proper rest overnight is sufficient to restore normal morning levels.

Stage 4: Next comes a stage at which, between the end of one day's work and the beginning of the next, there is inadequate time for return to normal blood pressure status.

Stage 5: Finally, a condition is reached in which even a weekend of proper rest away from exposure is inadequate to restore normality.

Of course, only very frequent medical examination will detect each of these progressing stages in workers, but properly timed additional examinations will easily show the stage at which a particular abnormal individual has arrived.

Length and Intensity of Exposures to Chemicals.—If, at any point beyond stage 1, the worker is exposed, even for a short time, *to higher concentrations of a harmful chemical*, there may be a rapid deterioration in his condition. In fact, he may respond in a manner out of all proportion to the actual intensity of the "acute" exposure. His response may be more drastic even than that of a hitherto unexposed individual suddenly subjectd to a very much higher concentration of the chemical. This mode of response is possibly the basis of the so-called "idiosyncrasy" of workers. It will be discussed more fully later.

It seems quite possible, from our studies, that serious organic injury from harmful chemicals occurs more often as the result of an acute exposure of relatively short duration, *superimposed upon the accumulated effects of a prolonged, low grade exposure*, than it does from individual, well isolated, acute incidents without the background of chronicity. This possibility, among others, should warn against too great reliance upon so-called "safe limits" of atmospheric concentration of harmful chemicals, except as a crude index against which to measure the efficiency of ventilating equipment. It should also emphasize the importance of *cleanliness* to prevent development of the chronic state by skin absorption, which may remain unnoticed until an atmospheric condition, suddenly superimposed, leads to drastic effects.

Even when a worker has reached stage 5, no organic injury need be present. If stage 5 is allowed to continue, clinically detectable poisoning will occur. But the prompt recognition of stages 2 to 5, and the improving of working conditions, the worker's manner of doing his job, his personal habits, or (if these remedies are not possible) a week or so of rest, can restore to absolute normality.

The anomalous situation seems to exist that a prolongation of the stimulation stage of exposure is, in chronic exposure, of more importance than progression to the depression stage, provided that this latter does not go as far as circulatory collapse. The stimulation stage is characterized by increase in diastolic blood pressure up to and beyond normal limits. Values between 90 and 110 mm. (sitting) may be observed. If these levels are maintained too long, they may become fixed and, ultimately, high systolic pressure also will develop, and lead to either permanent hypertension or myocardial damage.

Management of the Worker Who Has Reached a State of Depression.—The state of depression with low muscle tonus and low diastolic, systolic or pulse pressures (or all three simultaneously) can often be restored to normal in a few hours by the use of oxygen and complete rest. If this state exists for some time before attempts are made to remedy it, several days or three or four weeks of rest or a change of occupation may be needed to restore the normal. It is not sufficient merely to change the occupation to one with no exposure to chemicals. The new occupation must also be physically less severe than that in which the worker has acquired his abnormality. If this change of occupation or rest are not adequate, and the worker is returned to his previous job before his normal level is restored, the state of depression may involve great sensitivity to even low concentrations of a harmful chemical.

CONTRIBUTING CAUSES TO ILL HEALTH

It is highly important to remember that the trends in the initial physiological response to exposure to chemicals are not specific. They may be produced by any conditions which

interfere with normal chemical metabolic processes of tissues. Thus they may result from:

1. Improper nutrition (improper as to quantity, quality, timing, and especially vitamin content).
2. Improper medication (unnecessary or badly controlled use of the "sulfa" drugs).
3. Self-medication (the use of "pick-me-ups" containing aniline derivatives).
4. Unnecessary exposure to abnormal levels of temperature and humidity.
5. Unnecessary exertion, leading to fatigue.
6. Disease (which is, in essence, chemical poisoning).
7. Deprivation of oxygen (result of sudden transfer to great altitudes, or prolonged work in ill ventilated enclosures).
8. Any combination of one or more of the above, plus exposure to harmful chemicals.

The blood pressure scoring system and the stages of development of abnormal scores apply as well to these different conditions as to uncomplicated exposure to harmful chemicals. The superimposition of any one or more of this group upon workers during any of the five stages will result in a reaction which corresponds to intense exposure to a chemical, and may even lead to acute circulatory collapse. Conversely, exposure to chemicals, even of low intensity, may cause serious results if any of these conditions is present.

These seven factors may act quite independently of the worker's occupation. They are, very decidedly, situations over which he should have control, or might control, if he were properly advised. Their importance in any program of preventive medicine in industry warrants more complete discussion.

Nutrition

The problem of nutrition is receiving national attention, mainly because of the unexpected results of Selective Service medical examinations. It is certain that many people have not received properly balanced diets. In spite of statements to the contrary, it is probable that a seasonal deficiency, at least, of important vitamins is rather widespread. Our own studies of animals and human beings show that exposure to chemicals can interfere with the ordinary vitamin metabolism and that

those exposed to harmful substances can be protected, to a considerable degree, against the early stages of action of such substances by a maximal daily intake of *vitamins* C and B_1 especially. It is interesting to note that the group of symptoms listed as accompanying the early action of foreign chemicals are substantially the same as those found in clinical C and B_1 deficiency. Moreover, the lowered muscle tonus found in the "depression" reaction to chemicals is also present in C and B_1 deficiency.

The Use of Supplementary Concentrated Vitamin Preparations.—In some quarters, there appears to be opposition to the idea of amplifying the diet by giving concentrated vitamin preparations. In theory, this may be correct. In practice, a very intensive educational program would be required to remedy the dietary situation, and even if such a program were undertaken, regional habits as well as personal fads and fancies would act against complete success. It is important to realize that the diet must be adequate, not merely as to content, but also as to distribution during the day. The total daily intake may be ample, but if it is confined to one large meal, it may leave a rather long period during which the stomach is relatively empty. Experience with exposure to T.N.T., in England, during World War I, showed that improper distribution of meals could be a source of increased disability from chemical poisoning.

In many new war plants, the control of dietary habits is difficult. The size and layout of the plant make it useless to expect the men to go to a central cafeteria for lunch. It is, therefore, difficult to assure both adequacy of food intake and cleanliness of eating conditions. In such circumstances, remembering the results of inadequate diet in the last war, and taking into account such other evidence as has been collected on dietary deficiency and susceptibility to chemical poisoning, we feel it reasonable and proper to supplement workers' diets by daily concentrated vitamin preparations, containing at least maximal doses of C, B_1 and the other components of the B complex.

Medication

The drugs of the "*sulfa*" series are proving extremely valuable when properly employed. It does not detract from their value to point out that these drugs are far too widely and too carelessly used in clinical conditions for which they are not really necessary. Many frank cases of serious poisoning have occurred from them, but it is not sufficiently emphasized that even single therapeutic doses can produce marked and dangerous physiological effects. The following quotation from editorial correspondence in the *Journal of Aviation Medicine*[3] is significant:

> "The use of sulfanilamide in the treatment of disease has increased our care of flyer problems. The British have found that a single dose reduces a pilot's ceiling about 5,000 feet. We have had one death just after flying, from it, and one collapse. It is easily obtainable by anyone and, in fact, civilian doctors prescribe it without a thought of danger in relation to flying."

If a pilot flies above his "ceiling" (12,000 to 14,000 feet) without using oxygen, he passes rapidly through all the early stages of action of toxic chemicals to a state of circulatory collapse. When treated with sulfanilamide and similar drugs, he has progressed well toward stages 4 and 5 even before *flying, and a sudden decrease in the oxygen supply* may prove disastrous. In industrial medicine, the early action of a toxic chemical may closely simulate oxygen deficiency and may lead to the same results as are experienced in aviation.

The physiological effects of the "sulfa" drugs are rather lasting. We have record of at least one case in which a worker, having reached a stage of circulatory collapse, failed to recover, with rest, in the normal period of two to six hours. He was under treatment with a "sulfa" drug, merely because he showed an unexplained temperature. Actually, three weeks of rest were needed before a normal circulatory level was restored.

In a less serious degree, the same situation applies to *antiluetic treatment with organic arsenicals*. Indeed, we wonder whether a luetic under active treatment is not in greater hazard, when exposed to harmful chemicals, than a luetic not so treated. This problem is important if there is industrial

exposure to substances (such as chlorinated hydrocarbons or aromatic nitro compounds) which injure the liver.

Self-medication

The use of patented drug mixtures as treatment for headaches, and so on. is widespread. Some contain aniline derivatives, which are physiologically quite active. Such self-treatment can produce all the early stages of chemical exposure and render a worker more sensitive to materials which he may handle in industry.

There is no need to point out that excessive indulgence in alcohol can be considered here as self-medication.

Extremes of Temperature and Humidity

Unusual levels (high or low) of temperature. and high humidity with high temperature, do not usually affect well-nourished, normal persons. Studies over four years show that workers, in the early stages of action of harmful chemicals, react to high temperature by rapid circulatory deterioration. In fact, a definite seasonal trend in abnormality of a group of workers, studied by the blood pressure scoring system, is almost certain proof of a mass exposure to a harmful material.

This effect is distinct from the well known action of high temperature and humidity, which results from loss of salt and unusual fluid distribution. This condition can be controlled easily by increasing salt and fluid intake, plus the daily addition of 100 mg. of vitamin C to the diet. This latter is helpful because excessive perspiration leads to loss of vitamin C through the skin.

Unnecessary exertion during extremes of temperature (for instance. struggling through snowdrifts on the way to work, or too much physical activity during summer weekends) leads to fatigue of such a degree that, on return to work on Monday, a worker may not merely show a distinctly abnormal blood pressure score, but may also appear unusually sensitive to toxic chemicals used in his job.

Unnecessary Fatigue

Overexercise during the hours away from work may have a great influence on the trend of resistance to chemicals.

Medication

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In a less serious degree, the same situation applies to *antiluetic treatment with organic arsenicals*. Indeed, we wonder whether a luetic under active treatment is not in greater hazard, when exposed to harmful chemicals, than a luetic not so treated. This problem is important if there is industrial

"concentrations of carbon monoxide which are innocuous at sea level become dangerous at even moderate altitudes." This situation is not specific for carbon monoxide. It applies, also, to the action of hydrocarbon solvents used in manufacture of paints, and is operative when those paints are used in poorly ventilated rooms or cabins. It applies also to the household use of cleaning materials without proper ventilation.

CONCLUSION

This review of factors important in the control of health of workers, who may handle harmful chemicals, shows that maintenance of good health depends upon close cooperation between employer, physician, and worker. Upon no one of the three can be placed the entire burden of the problem.

It is the part of the *employer* to provide safe equipment, adequate physical safety devices, such as ventilating systems, or respirators or masks, where needed. He should provide proper medical attention, employing a competent physician, with necessary quarters and material for his medical work, and should cooperate in setting up and carrying out a proper medical program. He should also provide proper facilities for washing and changing from street to work clothing so that a worker cannot wear contaminated clothes to his home, and so prolong his possible exposure by skin contact.

The *physician* should acquaint himself with all phases of his problem, know in detail the procedures used in the plant, and by interest and sincerity, gain the confidence of management and each individual worker. A program of frequent medical studies will help by insuring close contact of worker and physician. Contrary to the belief of some employers and physicians, frequent medical examinations, properly conducted, do not alarm workers. Rather, they give workers the feeling of confidence.

The *employee* must also take his share of the burden. He must realize that his own behavior, during the sixteen hours each day in which he is away from the plant, and during the weekend, can bring success or defeat to the best efforts of his employer or his physician. There is, quite definitely, a possibility of "contributory negligence" of an employee. The

Often, in a routine program of study by the blood pressure scoring method, men are found to be in a very poor condition on Monday morning, but improve greatly during the week. In spite of a minimal exposure to harmful chemicals, the work period may act more as a "rest period" than the supposed "weekend rest" from work.

A very important factor in the Monday morning picture may be excessive automobile driving over the weekend. The fatigue of driving, plus inadequate or improper food intake, leads to physiological abnormality. In addition, there is, too often, the added factor of exposure to the carbon monoxide of exhaust gases. Few people pay much attention to the condition of mufflers and exhausts in their cars, and in cold weather are apt to close the car and reduce ventilation almost to zero level. We have one record of a man who, after a weekend of driving, appeared at work on Monday in a poor condition, and suffered circulatory collapse an hour or so later after a degree of chemical exposure which, as was clearly shown by records taken on him every two weeks for many months, would not usually give him an abnormal blood pressure score, and which did not affect other men in his group on the day in question.

Disease

Disease due to bacterial infections or parasitic infestation is really the result of chemical poisoning and can produce all the stages of abnormality indicated above. An attack of "grippe," or acute upper respiratory infection, can advance a worker so far on the route in physiological change that he may react to a low concentration of a toxic chemical by a drastic fall in blood pressure score.

Deprivation of Oxygen

Sudden reduction in the available oxygen supply, such as occurs in flying in high altitudes, or working in restricted, unventilated enclosures, will have the same physiological result as toxic chemicals. Such deprivation of oxygen will add to the effects of the chemical exposure, so that the combination may have drastic results. Thus, Heim[4] has shown that

"concentrations of carbon monoxide which are innocuous at sea level become dangerous at even moderate altitudes." This situation is not specific for carbon monoxide. It applies, also, to the action of hydrocarbon solvents used in manufacture of paints, and is operative when those paints are used in poorly ventilated rooms or cabins. It applies also to the household use of cleaning materials without proper ventilation.

CONCLUSION

This review of factors important in the control of health of workers, who may handle harmful chemicals, shows that maintenance of good health depends upon close cooperation between employer, physician, and worker. Upon no one of the three can be placed the entire burden of the problem.

It is the part of the *employer* to provide safe equipment, adequate physical safety devices, such as ventilating systems, or respirators or masks, where needed. He should provide proper medical attention, employing a competent physician, with necessary quarters and material for his medical work, and should cooperate in setting up and carrying out a proper medical program. He should also provide proper facilities for washing and changing from street to work clothing so that a worker cannot wear contaminated clothes to his home, and so prolong his possible exposure by skin contact.

The *physician* should acquaint himself with all phases of his problem, know in detail the procedures used in the plant, and by interest and sincerity, gain the confidence of management and each individual worker. A program of frequent medical studies will help by insuring close contact of worker and physician. Contrary to the belief of some employers and physicians, frequent medical examinations, properly conducted, do not alarm workers. Rather, they give workers the feeling of confidence.

The *employee* must also take his share of the burden. He must realize that his own behavior, during the sixteen hours each day in which he is away from the plant, and during the weekend, can bring success or defeat to the best efforts of his employer or his physician. There is, quite definitely, a possibility of "contributory negligence" of an employee. The

task of pointing this out to him lies chiefly with the industrial physician. But the plant physician, to function properly, should maintain close contact with and cooperate with the worker's *family physician*, who can also play a very important part in the whole program. The family physician should be familiar with his patient's occupation and, when his services are needed in treatment of sickness, make certain that his therapy is not harmful.

The present national crisis offers an admirable opportunity for the cooperative spirit, not merely in preventing sickness of workers in industry, but in preventing even the least disability. It presents an unprecedented occasion for establishing industrial medicine as a major field of national health control.

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METHODS EMPLOYED IN THE APPRAISAL AND CONTROL OF INDUSTRIAL HEALTH HAZARDS

J. J. BLOOMFIELD*

It is generally conceded that in order to obtain practical results in industrial hygiene, we need the combined efforts of the physician, the engineer, the chemist, and the nurse. Basically, we can divide our mode of attack on industrial hygiene problems into two parts: First, we must attack those problems concerned with the hygiene of the individual, and second, those dealing with the environment in which the individual works and lives. The first function comes within the scope of the medical sciences and has been treated adequately in the other contributions of this series. The second function deals with engineering practices and forms the basis for the present discussion.

Under medical sciences would come the allied professions—nursing and the various medical specialties, such as pathology and physiology. Engineering services would include, in addition to engineering, the work of other public health personnel, such as chemists, bacteriologists, and biometricians.

In other words, the functions coming within the province of the medical department are concerned with the individual, while the functions with which the engineer concerns himself deal with the environment.

Insofar as the *working environment* is concerned, it is within the province of the medical department to determine the existence of such diseases as may be due to the working environment, while on the basis of the physician's findings the engineer is in a position to learn what unhealthful conditions should be investigated and where control measures need

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to be initiated. It is essential therefore that the various professions clearly understand the functions of each, and approach the solution of the industrial hygiene problem as co-workers in a joint effort, cooperating with each other to the fullest extent.

Ill health and premature death have been associated with the nature of man's livelihood from time immemorial. Studies in recent years have clearly indicated that the health of workers engaged in industry can be affected by the conditions, materials, and processes of work. For these reasons, important functions in industrial hygiene are the study of the workroom environment and its effect on health, and the subsequent development of methods for the control of environmental hazards.

It is realized, of course, that in ordinary times the worker spends only approximately one-third of his day at his place of employment. His health can therefore also be influenced by his *home* and *recreational environment*. These latter conditions may also bear an important relationship to the so-called nonoccupational diseases, which are a major cause of time lost from work. For this reason, attention must also be given to factors outside the workroom which might have a bearing on a worker's health and efficiency. The present article will be limited to a discussion of the working environment only.

If we examine the literature on industrial hygiene, we are confronted with the fact that methods employed in the study of the effect of industrial health hazards differ but little from those used in investigations of other phases of public health. This is not strange, since in the studies of industrial diseases it is essential, as in communicable disease investigations, to determine the etiology, pathology, symptomatology, and the application of measures to prevent or control the disease. One may therefore employ the term "industrial epidemiology" when referring to the methods used for the investigation of diseases occurring in industry or among industrial workers, and the subsequent determination of methods of prevention or control of such diseases.

It is the purpose of the present discussion to treat of some of

the methods which are employed in those phases of industrial epidemiology dealing with the workroom environment.

THE STUDY OF THE WORKROOM ENVIRONMENT

The Reconnaissance Survey

One of the functions of an engineer in the field of industrial hygiene is the study of the workroom environment in an effort to determine any relationship between that environment and its effect on the health of the worker. In all such investigations there are certain preliminary steps of fundamental importance which must be undertaken in order to serve as a guide in the more detailed studies which may be indicated. These preliminary steps are the basis for the reconnaissance survey and consist in the sanitary appraisal and the occupational analysis of the workroom and its inhabitants.[1]

The *sanitary survey* of the workroom consists in noting items of a general sanitary and hygienic nature, such as provisions for ventilation, illumination, fire protection, accident protection, exposure to specific poisons, such as dusts, fumes, vapors, and gases, fatigue, and so on. In other words, the sanitary survey yields information concerning the presence of various health hazards and serves as a guide in determining which hazards require further detailed study in the nature of actual quantitative determinations. One should look upon this type of survey as a listing of the facilities afforded the worker while in the industrial environment, and may be likened to the inventory of materials in stock which a business establishment usually undergoes periodically.

The *occupational analysis*, which is also a part of this inventory or reconnaissance survey, permits one to learn of the activities involved, the particular hazards associated with each occupation, and the number of persons in each occupation.

In order to assist the engineer in the conduct of such reconnaissance surveys, certain *forms* are recommended. One form lists data of a general nature. It covers items of a sanitary character in order to provide information on housekeeping; provision of certain personal services, such as cloak rooms, locker rooms, showers, and toilets; and information on vari-

to be initiated. It is essential therefore that the various professions clearly understand the functions of each, and approach the solution of the industrial hygiene problem as co-workers in a joint effort, cooperating with each other to the fullest extent.

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It is realized, of course, that in ordinary times the worker spends only approximately one-third of his day at his place of employment. His health can therefore also be influenced by his *home* and *recreational environment.* These latter conditions may also bear an important relationship to the so-called nonoccupational diseases, which are a major cause of time lost from work. For this reason, attention must also be given to factors outside the workroom which might have a bearing on a worker's health and efficiency. The present article will be limited to a discussion of the working environment only.

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chemist have at their disposal delicate instruments and methods of analysis unprecedented in the history of industrial hygiene, and our knowledge concerning such matters is increasing from day to day. The guesswork as to actual exposures has been fairly well taken out of industrial hygiene.

A second purpose served by the detailed study is the fact that if clinical investigations are made concurrently with environmental studies, the findings on occupational exposure may indicate the permissible amounts of the toxic materials which may be tolerated with safety.

And, finally, the third purpose served by this type of study deals with the control of the hazard. In other words, one is in a position to determine the efficiency of any device

TABLE 1

LEAD EXPOSURE AND MAXIMUM MONTHLY RATE OF INITIAL COMPENSATION CASES FOR PLUMBISM

Department	Milligrams of Lead per 10 Cubic Meters of Air	Maximum Monthly Rate (per 100)
Mixing	120.0	44.0
Pasting	50.0	12.0
Burning	5.7	4.4
Casting	1.2	.18

which may have been introduced for the minimization or elimination of the hazard.

Some examples illustrating each of the three purposes served by the detailed study follow.

Extent of Hazard.—In a study of lead poisoning among storage battery workers, it was important to determine the relationship between the amount of lead dust inhaled by the men and the incidence and severity of plumbism. Such a study is valuable in that it may indicate the maximum amount of lead which may be inhaled with impunity.

Table 1 shows the fundamental correlation between the lead dust in the air and the rate of plumbism in the major departments of the plant in which a study was made.[3] It is evident that a close correlation exists between the lead

ous control measures which may be in use, such as ventilation and safety devices. Space is also provided for the listing of exposures to certain hazards arising from fumes, gases, dusts, and specific poisons. Another form deals primarily with the individual occupation, providing space for the designation of the occupation, the number of persons involved, the nature of the work itself, and the raw materials and by-products associated with each occupation. Space is also provided for noting control measures associated with each exposure and individual occupation.

In practice, the reconnaissance survey consists of carefully filling out the two inspection forms and jotting down any additional notes on items which may not be provided for in the forms under discussion. After filling out the survey forms for each workroom in an entire plant, a detailed analysis of the data contained in the forms is then in order. It is such an analysis that enables one to furnish a complete picture of the hygienic conditions in each of the workrooms studied and in the plant as a whole.

The Detailed Survey

In determining a worker's exposure to materials or conditions incident to his employment, it is necessary to have precise data on such exposures. In some cases the difference between a hazardous and a nonhazardous condition may depend entirely on whether the worker is exposed continuously to concentrations of materials bordering on the threshold limit. For example, in the case of exposure to certain lead compounds, for which the threshold limit has been set as 1.5 milligrams per 10 cubic meters of air, it is very important to know whether the worker is inhaling lead dust approximately above or below this limit. Quite often a difference of a milligram or so may spell the difference between a safe or an unsafe condition.

Detailed appraisals of exposure may be said to serve a *threefold purpose*. First, they enable one to determine the extent of a hazard. This is accomplished by obtaining occupational exposures, by precise methods, to the toxic materials or conditions under consideration. Today, the engineer and

in industrial hygiene are constantly increasing in number, especially now when many new chemicals and processes are being introduced into our war industries. Our knowledge of these substances, as to their action on the body, is constantly being augmented by the work of toxicologists and by field studies of the type described herein. It is the engineer's task, once this knowledge is available, to devise ways and means for controlling these injurious materials and conditions, a discussion of which follows.

THE CONTROL OF INDUSTRIAL HEALTH HAZARDS

The control of industrial health hazards is also a function of the medical and engineering departments. The *physician* and his co-workers recognize the existence of diseases due to the workroom environment and exercise medical supervision and initiate studies designed to eradicate dangerous conditions. The *engineer* and his co-workers determine the extent of the hazard, and, armed with a knowledge of the toxicity of the material involved, are in a position to consider methods and equipment for the control of the hazard.

No set rules may be established for the mechanical protection to be instituted in an attempt to control an industrial health hazard. Specific conditions encountered in a plant will determine the type of protection to be employed. In general, however, there are five methods which may be attempted in the minimization of an industrial exposure. These are: (1) substitution of a nontoxic material for the toxic one, (2) isolation of the harmful process, (3) wet methods in the case of some dusty operations, (4) local exhaust ventilation, and (5) respiratory protection. In many instances it may be necessary to employ a combination of the above methods in the control of a single exposure.

Substitution

The protection of workers against certain dusts known to be toxic may at times be accomplished by the substitution of a nontoxic material for the toxic one. One example of such a procedure is the use of a metallic or other type of artificial abrasive for sand in the sandblasting process in those opera-

exposure of workers in different departments and the risk of developing a case of lead poisoning.

Correlation with Clinical Data.—Figure 163 illustrates the relationship between lead dust exposure, years of exposure, and the percentage of exposed workers with diagnosed early plumbism.[4] It is evident that 1.5 milligrams of lead dust per 10 cubic meters of air, except for very prolonged exposure, is the limit of safety under the conditions encountered in these studies. This important finding is of great value to the

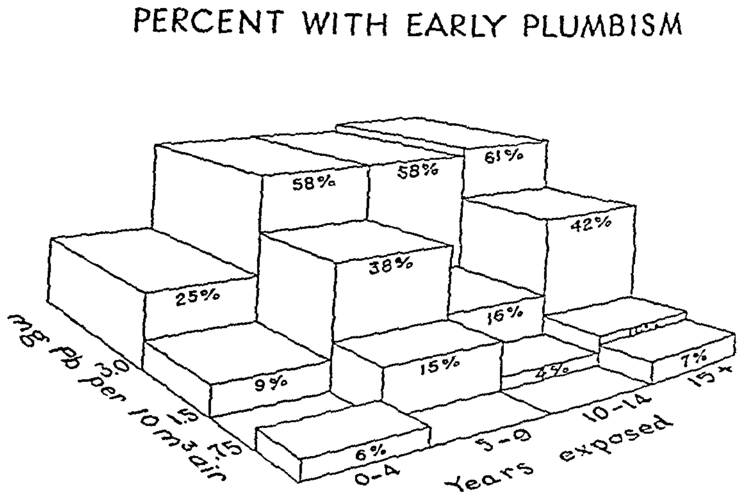

Fig. 163.—The percentages of storage battery workers in each of 16 exposure groups in whom early plumbism was diagnosed are represented by the heights of blocks. Thus, of the workers exposed more than fifteen years to atmospheric lead concentrations in excess of 3 mg. Pb per 10 m³ of air, 61 per cent were found to have early plumbism.

engineer, since it gives him a basis upon which to develop protective devices in the way of exhaust ventilation, respiratory protection, good housekeeping, and so on.

Efficacy of Control.—The detailed survey as employed in studying the efficiency of various methods employed for the control of a hazard will be treated in more detail in the next section, which deals with the control of industrial health hazards. It is desired, however, in closing this portion of the discussion, to point out that the engineering problems

in industrial hygiene are constantly increasing in number, especially now when many new chemicals and processes are being introduced into our war industries. Our knowledge of these substances, as to their action on the body, is constantly being augmented by the work of toxicologists and by field studies of the type described herein. It is the engineer's task, once this knowledge is available, to devise ways and means for controlling these injurious materials and conditions, a discussion of which follows.

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tions in which it is not necessary to use sand, a substance high in quartz content. The data shown in the accompanying table (Table 2) indicate clearly the lowering in dust concentration when a steel abrasive is employed instead of sand in a sandblasting room.[5]

TABLE 2

REDUCTION IN CONCENTRATION AND QUARTZ CONTENT OF DUST IN SANDBLAST ROOMS BY THE SUBSTITUTION OF STEEL FOR SAND ABRASIVE

Type of Abrasive	Average Dust Concentration in Millions of Particles per Cu. Ft.	Percentage of Quartz
Sand	969	42–98
Steel	155	3

Another example of substitution is one recently employed in the hatting industry. For more than 100 years mercury had been employed in the carroting solution which was applied to rabbit fur utilized for the production of felt hats. Certain operations in the preparation of the hatters' fur and in the

TABLE 3

DUST CONCENTRATIONS FOR SANDBLAST INSTALLATIONS REGARDED BY MANUFACTURERS AS "IDEAL" IN COMPARISON WITH OTHER EQUIPMENT

	Average Dust Count in Millions of Particles per Cubic Foot		
	Barrels	Tables	Cabinets
Ideal	1 7	0 2	1 9
Other	29 0	22 0	38 0

subsequent manufacture of the hat itself entailed exposure to mercury vapor and dust with accompanying mercurialism among the workers. Recently the hatting industry itself developed a nonmercurial carroting solution which was adopted by the industry, so that mercurialism in the future will be completely eradicated in this industry.[6]

Isolation

The mechanical enclosure or isolation of certain operations also serves to protect the worker. In the case of dust exposure, we have an excellent illustration of this type of protection by the use of the modern sandblast barrel used in the cleaning of small objects. The following table illustrates the practical elimination of dust exposure in certain sandblasting operations in which well enclosed and isolated operations are contrasted with those not offering this sort of protection.

Wet Methods

In the case of dust, it is possible to protect workers by the substitution of wet for dry processes. This method is illustrated by the results shown in the following table.

TABLE 4

CONTRASTING WET AND DRY METHODS OF ROCK DRILLING AND LOADING

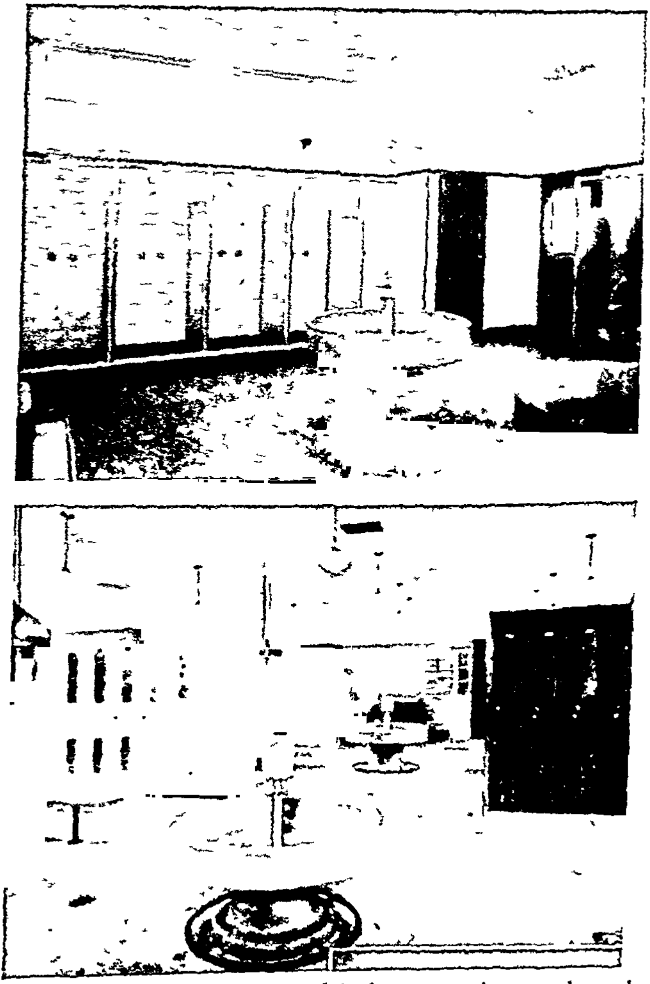
Processes	Number of Samples	Average Dust Count in Millions of Particles per Cubic Foot	
		Dry	Wet
Drilling	23	568	33
Loading	10	636	32

More recent studies of rock drilling operations have shown that wet methods employed in conjunction with general exhaust ventilation may often result in even lower dust concentrations than those shown in the above table.[7]

Local Exhaust Ventilation

Perhaps the most universally used method of control of certain workroom conditions which are harmful to health is local exhaust ventilation. This method aims to remove dusts, fumes, vapors, and gases at their source. So much depends upon the correct design and construction of hoods and exhaust systems that they should be laid out and maintained with great care. The past few years have witnessed

the gradual accumulation of a tremendous amount of basic engineering data on this type of control. Data pertaining



Figs. 164 and 165.—Tiled shower and locker rooms in a modern plant.

to quantity of air necessary at hoods to control hazards or nuisances are rapidly accumulating.

For example, it has been shown that spray painting booths

require velocities of 100 to 200 feet per minute at the openings to reduce effectively the presence of vapors to safe limits. For laterally exhausted chromium plating tanks, specific air velocities and air volumes have been developed

TABLE 5

MINIMUM AIR VELOCITIES REQUIRED TO CAPTURE CERTAIN INDUSTRIAL DUSTS AND VAPORS

Industry	Process	Required Air Velocity		Criterion
		At Point of Origin	At Face of Hood	
Granite cutting	Hand pneumatic tool	200 FPM	....	Reduced concentration to safe level
	Surfacing machine	1500 FPM	....	Reduced concentration to safe level
	All tools	....	1500	Reduced concentration to safe level
Grain elevators	Elevator boot and head, garner	....	500	Visual test
Paint spraying	Spraying booth	....	50–200	Reduced concentration to safe level
Sand pulverizing	Bagging machine	400 FPM	....	Reduced concentration to safe level
Quarrying and mining	Horizontal drilling with Kelley trap	60*	....	Reduced concentration to safe level
	Vertical drilling with Kelley trap	200*	....	Reduced concentration to safe level
Electroplating	Chromium plating	50†	1500	Reduced concentration to safe level
	Steam and acid tanks	75–100	....	Reduced concentration to safe level
Hatters' fur	Brushing	200*	....	Usual practice
	Cutting machines	350*	....	Usual practice
	Blowers	2000*	....	Usual practice
Electric welding	Welding	200	....	Visual test
Metal spraying‡	Lead Zinc	200 125	....	Effective removal of all fumes

* Cubic feet per minute.
† Cubic feet per minute per foot of slot (common practice).
‡ At opening of booth.

and are now embodied in a national standard recently promulgated by the American Standards Association.[8] In connection with granite-cutting, special hoods have been designed for the control of the hazard in this industry.[9] In

certain instances, down-draft ventilation has been found to be most effective. Such practice materially reduces the air velocities required for control and utilizes a natural tendency for heavy dust to settle.[10]

The scope of the present article does not permit adequate treatment of this particular method of control, although when properly considered it is an effective one. The accompanying table presents some data concerning required air volumes and other pertinent information regarding local exhaust ventilation.

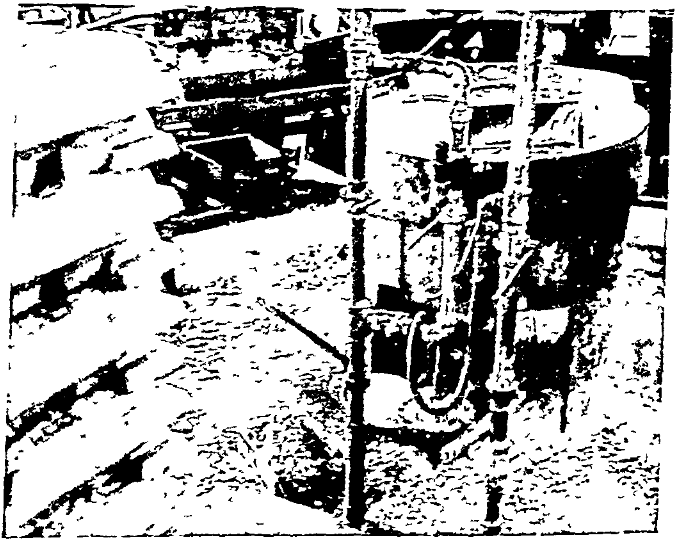


Fig. 166.—Lead melting pot without hood. Note dross and spilled lead on floor.

Respiratory Protection

It is generally agreed that in the control of exposures to air-borne toxic materials, primary consideration should be given to procedures for preventing excessive contamination of the air in the breathing zone. However, there will always be situations where these procedures will be inapplicable, impracticable, or at times not effective. For these situations, personal respiratory protection will be required, either as a primary means of protection or as an adjunct to other pre-

ventive procedures. In recent years, great strides have been made in the improvement of respiratory protective devices and at present the United States Bureau of Mines is approving such devices after rigid testing.[11] Such an approval system has stimulated further research on the part of the manufacturers handling these devices, which has resulted in a better product. The reader is referred to an excellent treatise on respiratory protective devices which was prepared by the Subcommittee on Personal Respiratory Protective Devices of the Committee on the Prevention of Silicosis through Engineering Control of the National Silicosis Conference.[12]

It is also not possible to include in the present discussion the important subject of protective clothing, such as goggles, aprons, boots, rubber gloves, and especially the newer types of protective clothing made from plastics, nor is it practicable to go into a discussion of the subject of protective ointments. The reader is referred to the excellent articles on this subject by Dr. Louis Schwartz.[13, 14]

SUMMARY

The Need for a Study of Existing Control Measures

Today we are witnessing vigorous action on the part of many official organizations in the development of codes and other regulations dealing with the removal of noxious airborne materials and other environmental hazards in industry. Nonofficial agencies, such as the American Standards Association, and various medical and engineering organizations, are collaborating with state and federal agencies and industry toward the development of such codes on a scientific basis. One of the great needs today to aid in the development of such codes is factual data based on studies of existing installations.

It is well-known that in many industries health hazards are being effectively controlled. The engineer and the clinician should systematically evaluate the efficiency of the various methods employed so that the data would be available and useful in the preparation of good practice codes.

Perhaps it would be proper at this point to give an ex-

certain instances, down-draft ventilation has been found to be most effective. Such practice materially reduces the air velocities required for control and utilizes a natural tendency for heavy dust to settle.[10]

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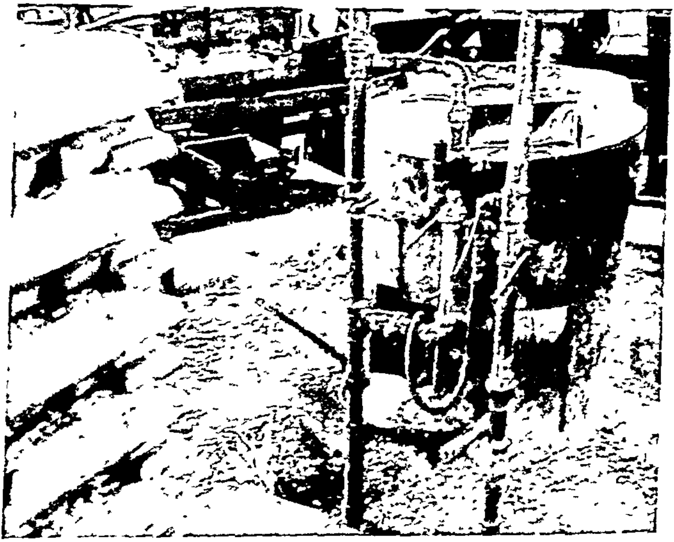

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The Setting of Basic Standards

With further reference to basic standards for the control of hazards in industry, two approaches may be employed. *Standards can be based on clinical data,* that is, on definite knowledge which shows that exposure to more than a certain amount of a toxic material will involve injury to health. Such knowledge then can be used in engineering design in order to reduce the exposure within the so-called threshold limit.

TABLE 6

EXPOSURE OF HATTERS' FUR WORKERS TO MERCURY VAPOR AND TREATED FUR DUST UNDER CONTROLLED AND UNCONTROLLED CONDITIONS

Occupation	Total Mercury Exposure in Milligrams per 10 Cubic Meters		Average Air Flow C. F. M.	Method of Control
	Uncontrolled	Controlled		
Drummers	2.5	0.6	.	Segregation
Clippers	1.5	0.7	. . .	Segregation
Brushers	3.1	1.2	300	Local exhaust ventilation
Cutters	4.0	1.8	383	Local exhaust ventilation
Sorters*	3.8	1.7	383	Local exhaust ventilation
Blowers	4.6	0.7	2000	Local exhaust ventilation
Pilers	5.4	Trace		Good natural ventilation
Storage workers and shippers	7.2	Trace	.	Good natural ventilation

* Depend on exhausted cutters.

Although our knowledge concerning the toxicity of materials is rapidly becoming more and more abundant, there are still many substances for which we have no basic information at this time concerning their toxicological properties. In such cases it is suggested that *standards could be employed which are based on results which can be obtained by good engineering practices.* Quite often these engineering practices are found to yield conditions far better than those which might be based on our present knowledge of the toxicity of a material. One must bear in mind that our present ideas concerning the toxic limits of certain sub-

ample of the usefulness of a study of existing installations. In a survey of the mercury hazard in the hatters' fur cutting industry, the engineers were in a position to evaluate various control measures in vogue in various representative plants in the industry.[15] Table 6 indicates the exposure to mercury dust and vapor of some of the workers in this industry under controlled and uncontrolled working conditions. It is apparent that where some measure of control is practiced by such methods as segregation or local exhaust ventilation, a

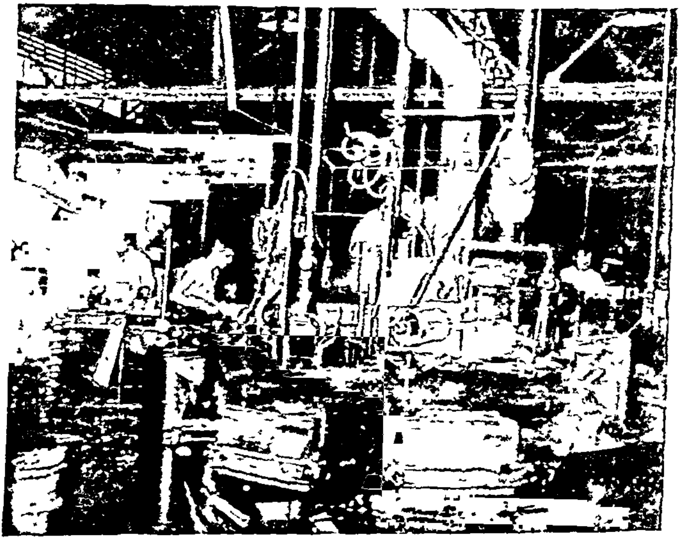

Fig. 167.—Automatic casting machines with local exhaust.

material reduction in the exposure to mercury is effected. Although no one plant was found to have all of the control measures in effect as shown in the table, methods were found in representative plants of the industry showing that the mercury exposure for different occupations could be controlled by existing practices. The engineer, in conducting a study of this type in representative plants, is in a position to present to the industry as a whole information showing how certain hazards can be and are being effectively controlled.

The Need for Continuous Study of Environment

Once the problem in industry has been evaluated and everything possible has been done to control unhealthful conditions, it will still be essential for the medical, nursing, engineering, and chemical personnel to maintain close vigilance, in order that safe conditions may be maintained and improved upon. Constant study of the workroom environment is essential to ascertain whether certain measures are really effective. Such practice in cooperation with the work of the physician and the nurse appears to afford the best means of controlling industrial health hazards, and their attendant loss of valuable time from work.

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stances are subject to change as our methods of diagnosis and analysis improve. For this reason, it is quite often more practicable to employ standards which are *based on good practices*, such as those resulting from engineering control.

In closing, it is desired to emphasize that studies of the industrial environment necessitate numerous laboratory examinations of a clinical, physical, and chemical nature. These, call for highly trained chemists and biochemists. Today,

Fig. 168.—Group burning—continuous conveyor. Numerous local exhaust hoods and air-line respirators.

with the added use of chemicals in many of our processes, there is a greater need for data concerning the toxic effects of these substances. The proper procedure is a study of these new materials or processes on a small scale prior to their widespread use in industry. This practice, which is now being employed in some of our more progressive industries, calls for a close collaboration between the production and development departments in the plant, and the industrial health maintenance service.

The Need for Continuous Study of Environment

Once the problem in industry has been evaluated and everything possible has been done to control unhealthful conditions, it will still be essential for the medical, nursing, engineering, and chemical personnel to maintain close vigilance, in order that safe conditions may be maintained and improved upon. Constant study of the workroom environment is essential to ascertain whether certain measures are really effective. Such practice in cooperation with the work of the physician and the nurse appears to afford the best means of controlling industrial health hazards, and their attendant loss of valuable time from work.

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The Medical Clinics of North America
July, 1942.

INDOOR ENVIRONMENTAL ATMOSPHERE AND ITS CONTROL

W. J. McCONNELL, M.D.*

THE REGULATION OF BODY TEMPERATURE

THE condition of the surrounding atmosphere in which we live and work is of vital importance to the well-being of us all. An important function of the environmental atmosphere is the part it plays in the regulation of body temperature. The ability of the human body to adapt itself to varying external temperature conditions depends almost entirely on the relation between the rate of heat production and heat dissipation. The body must make continual adjustment through its heat regulating mechanism in order to maintain the indispensable constancy of body temperature.

Variable amounts of heat derived from the food, drink, and air consumed are constantly produced within the body as a result of tissue oxidation. The basic rate is approximately 400 calories per square meter per hour. During muscular work, heat production may rise to twenty, thirty, and even forty times the resting rate. Heat loss, on the other hand, with the exception of relatively small quantities which are carried away in the body excretions, is accomplished through the lungs and body surfaces. Approximately 80 per cent is lost to the environment from the skin by *radiation*, *convection*, *evaporation*, and *conduction*.† The rate of heat disposal by each method is governed by the physical properties of the air, namely, the temperature, the moisture content, and the amount of air movement. Certain other factors, such as metabolic rate, vaso-motor control, activity, age,

* Assistant Medical Director, Metropolitan Life Insurance Company.

† *Radiation:* giving off of heat rays in all directions. *Convection:* transmission of heat by means of currents of air or water. *Evaporation:* loss of heat by changing of a liquid (perspiration) to a vapor. *Conduction:* flow of heat from a warmer substance to a cooler one.

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comfort is best attained in an atmosphere wherein a person loses an amount of heat corresponding to that generated, without being conscious of any adjustment made.

PHYSICAL PROPERTIES OF AIR; EFFECTIVE TEMPERATURE

The three physical air properties, *temperature, moisture content*, and *air movement*, may be considered as interdependent to an extent which makes it desirable to consider them as a unit rather than as separate factors insofar as their thermal adjustment and the result of that adjustment on comfort is concerned. The engineering profession has combined these into a single value called "effective temperature."

Reading Temperature

The temperature of the air may be readily determined by reading on the scale of the ordinary mercury thermometer the numeral opposite the level of the mercury in the stem of the thermometer. This reading indicates the *dry bulb* temperature of the air.

The *wet bulb* temperature is determined by covering the bulb of an ordinary thermometer with a moistened piece of gauze and fanning or whirling the thermometer so as to evaporate the moisture rapidly. The reading of the wet bulb is then made in the same manner as the dry bulb temperature, after the mercury has attained the lowest level.

A variety of *instruments* for determining the dry and wet bulb temperatures simultaneously are available, and these vary from the type giving approximate information to those of the recording type which give a continuous record for desired periods of time.

The *sling psychrometer* (Fig. 169) is a portable and very convenient variation of this latter type of instrument. It consists of two thermometers adjusted to a plate arranged to swing at the end of a short chain or about a swiveled handle. One of the thermometers is used for measuring the dry bulb temperature, and is a standard instrument such as is used ordinarily for the purpose; the bulb of the other thermometer is covered with a piece of wicking or gauze

clothing worn, personal habits, adaptability, and the state of health, also affect the rate of heat loss from the skin.

Under normal air conditions, thermal radiation goes on constantly from the body and may be responsible for as much as 60 per cent of the total heat lost from the body surfaces. Convection accounts for about 15 per cent when the body is at rest, but may be twice as much when the surface of the body is exposed to currents of air or water. Evaporation accounts for about 25 per cent. Heat lost or gained by conduction depends on the temperature of the conducting surface, the area of contact, and the specific conductivity of the conducting surface and of the body tissues.

Effect of Weather on Body Heat.—It would be erroneous to postulate any constant values for heat loss because of the inconstancy of weather conditions or body surface exposed. During the warm season the amount of heat which can be lost by radiation and convection is less than the amount that can be lost through these media in cool weather. Under the former condition, therefore, it is necessary for the body to lose more heat by evaporation of perspiration in order to maintain a constant body temperature. Heat loss by evaporation obviously is less effective in hot and humid atmospheres, or in densely occupied areas during the summer seasons because of the high moisture content of the air. Under such circumstances comfort can best be obtained by reducing both the dry bulb and dewpoint temperatures,* thereby increasing the amount of body heat that can be lost by evaporation and convection, and as the average temperature of the internal wall surfaces of the enclosure drops due to the reduction in the dry bulb temperature the amount of body heat lost by radiation also increases.

While circumstances may permit of the adjustment of only one of the physical factors of the air to the exclusion of the others, advantage should be taken of all methods of heat disposal wherever it is at all practical to do so. Human

* *Dry bulb temperature:* temperature of the air as measured by the ordinary thermometer. *Dewpoint temperature:* temperature at which precipitation occurs.

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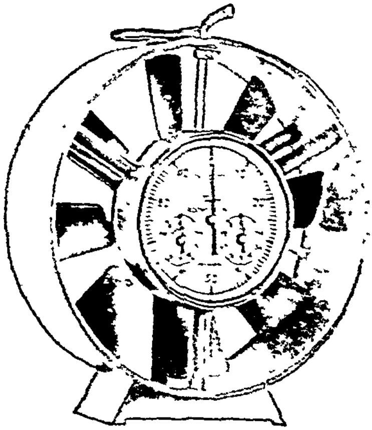

Fig. 170.–Anemometer. (Courtesy of Taylor Instrument Co., Rochester. N. Y.)

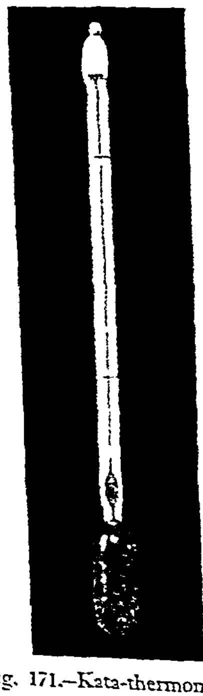

Fig. 171.–Kata-thermometer.

which is moistened with water just before whirling the instrument, and records a lower temperature than the dry bulb, unless the atmosphere is saturated.

Humidity

After determining the dry and wet bulb temperatures the relative humidity of the air can be ascertained by reference to tables or psychrometric charts. Tables have been prepared by the United States Weather Bureau (obtainable at the cost of ten cents from the Government Printing Office, Washington, D. C.) which give the percentage of relative humidity for any combined dry and wet bulb temperatures.

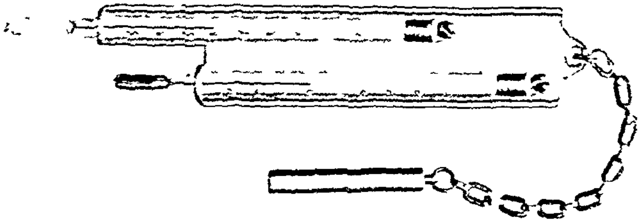

Fig. 169.—Sling psychrometer. (Courtesy of Precision Thermometer and Instrument Co.)

Measurement of Air Motion

Air motion may be determined in a variety of ways. Any one of the many types of *anemometers* (Fig. 170) on the market may be used for the measurement of the higher air velocities.

The *kata-thermometer* (Fig. 171),* designed by Sir Leonard Hill, can be conveniently used as an anemometer and constitutes, especially at low velocities, a useful instrument for readily detecting drafts or air infiltration through windows. It sums up undirectional air eddies and currents, and is in this way superior to any vane anemometer. Fundamentally, it is a specially constructed alcohol thermometer with a cylindrical bulb about four centimeters in length and

* "The Science of Ventilation and Open Air Treatment," Part I, Leonard Hill, H. M. Stationery office, London, 1919. The kata-thermometer can be purchased in the United States from H. N. Elmer (sole agency), 53 West Jackson Boulevard, Chicago, Ill.

A *high temperature kata-thermometer** which cools from 130° to 125° F. is recommended for determining the air velocity in instances where the temperature of the atmosphere exceeds 90° F.

The *Alnor velometer* (Fig. 172) is a portable instrument that measures instantly and directly both high and low air velocities, as well as air pressures. The standard velometer

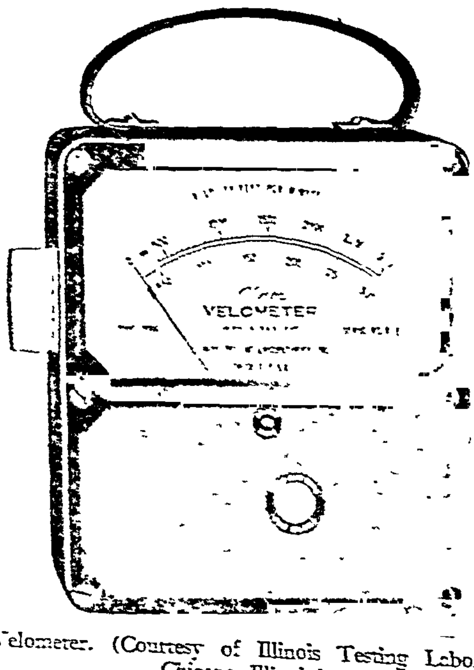

Fig. 172.—Velometer. (Courtesy of Illinois Testing Laboratories, Inc., Chicago, Illinois.)

is provided with a two-range scale; the low range (generally 0-250 or 0-300) provides accurate velocity readings as low as 20 feet per minute, and the high range will give correct readings up to its maximum scale. Special scales with either single, double, or triple ranges can be furnished with the

* "A New Kata-Thermometer for Hot Atmospheres and a Simplified Method for Computing," T. C. Angus, Leonard Hill and H. E. Soper, Journal of Industrial Hygiene, Vol. XII, No. 2, p. 66 (Feb.), 1930.

two centimeters in diameter. The top and bottom of the bulb are hemispherical. The stem, 20 centimeters in length, is graduated in tenths of a degree Fahrenheit from 95° to 100°. In some of the later models these calibrations have been omitted and markings represent the 100° and 95° points. An enlargement of the bore at the top of the stem serves as a safety reservoir in case of accidental overheating, and it also permits the instrument to be heated considerably above 100° F., so that by the time it is suspended in the desired position it has acquired a uniform rate of cooling.

In taking a reading, the kata is immersed in hot water until the alcohol rises to the top reservoir. The bulb is then dried and the instrument is suspended in the selected location. The time taken for the fluid to fall from 100° to 95°, measured by a stop watch, is a criterion of the heat loss from the surface of the kata by radiation and convection. Since the heat loss from the surface of the kata in dropping from 100° to 95° is a known factor (and is written in the back of the thermometer in millicalories per square centimeter of kata surface and is known as the "kata factor"), the rate of the loss depends entirely upon the atmospheric environment. It is obvious, therefore, that there exists a definite relation between the time of cooling of the kata-thermometer and the atmospheric conditions. The rate of heat loss is determined by dividing the kata factor by the time of cooling, in seconds, from 100° to 95° F. After determining the rate of heat loss and ascertaining the dry bulb temperature by an ordinary thermometer, the air motion is easily calculated by means of a formula or table.*

More recently Yaglou and Dokoff† have calibrated the kata-thermometer over a wide range of accurately controlled air conditions, so that it can be used satisfactorily for high or low temperatures and humidities and for any air velocity between 0 and 650 linear feet per minute.

* "Report of Committee on Standard Methods for Examination of Air," American Public Health Association, Am. J. Public Health, Vol. 7, No. 1, Jan., 1917.

† "Calibration of the Kata-Thermometer Over a Wide Range of Air Conditions," C. P. Yaglou and Kroum Dokoff, Journal of Industrial Hygiene, Vol. XI, No. 8, p. 278 (Oct.), 1929.

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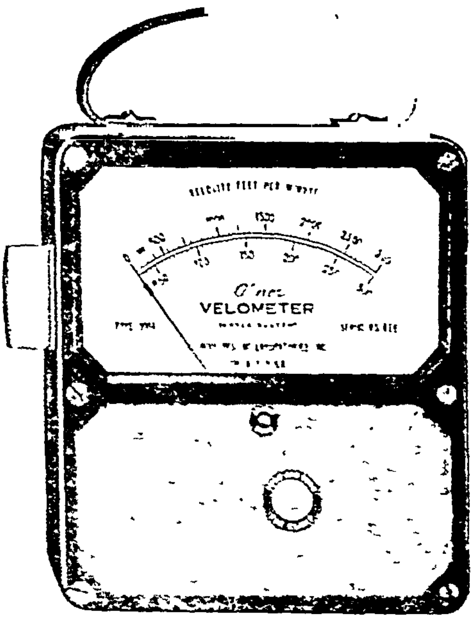

Fig. 172.—Velometer. (Courtesy of Illinois Testing Laboratories, Inc., Chicago, Illinois.)

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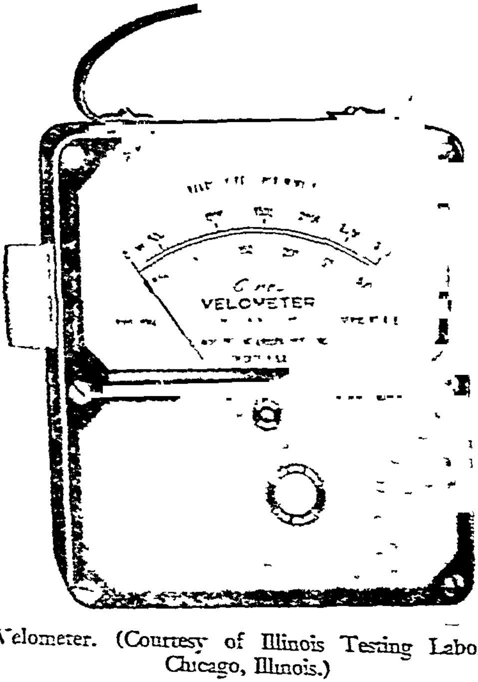

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velometer which give from as low as 15 feet per minute up to as high as 18,000 feet per minute.

Final Analysis of Effective Temperature

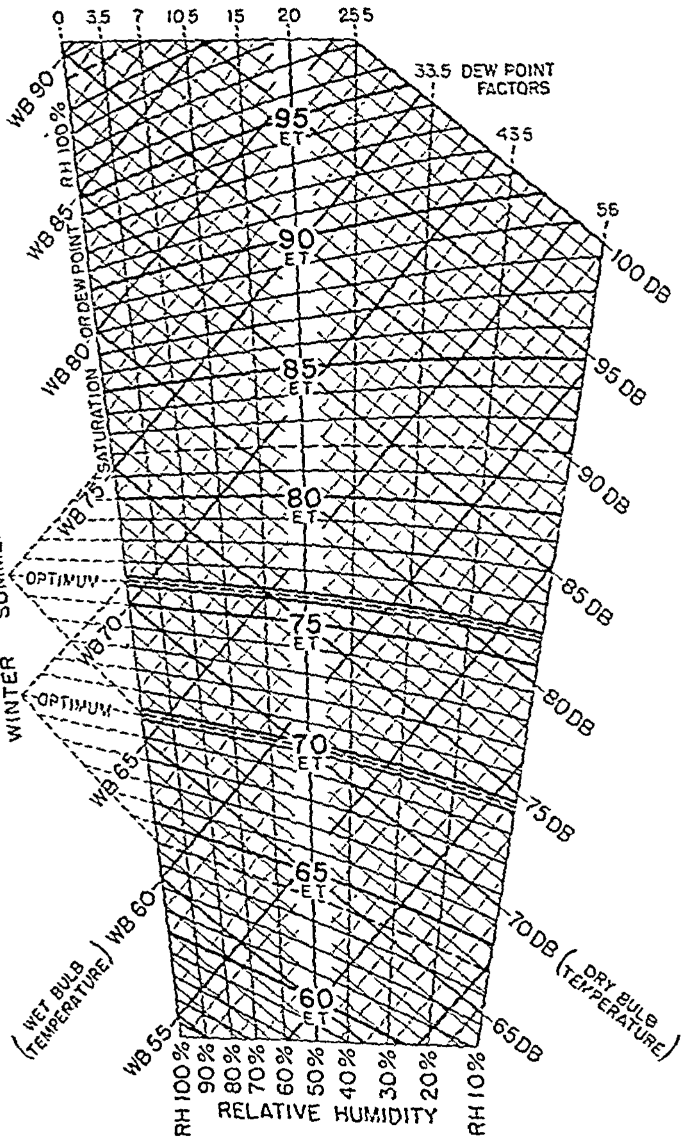
The "effective temperature," which is based on experimental work, using human beings as subjects, conducted by the Research Laboratory of the American Society of Heating and Ventilating Engineers in cooperation with the United States Public Health Service and the United States Bureau of Mines,* in reality is not a temperature of the air, but is a *relative index of the temper of atmospheric conditions felt by the human body in response to temperature, humidity, and movement of air.* It follows, therefore, that all combinations of these air properties which are thermally equivalent to each other have the same "effective temperature." The "effective temperature" scale, for convenience in application, has been superimposed upon a standard psychrometric chart.

"Normal" Effective Temperature.—The fact that saturated air is the basis of the effective temperature index, instead of a relative humidity of 50 per cent which is an average under ordinary conditions of humidity, has led to some confusion in the lay mind, since the majority of people still interpret comfort in terms of the dry bulb temperature at normal humidities.

Recognizing that the valuable work represented in the effective temperature index would have more ready acceptance by the public if put into terms more comprehensible to the layman, Parsons and Bailey, in collaboration with others, revised the existing or basic scale by changing the basis from saturated air to 50 per cent humidity, and named the revised scale "normal effective temperature" (Fig. 173).

Both scales are based on air movements of approximately 15 to 20 feet per minute, or practically still air. For higher velocities, deductions must be made from the schedule, depending upon the amount of air movement. The effective

* The results of these experiments have been published in the Society's Journal in a series of articles beginning in 1923 and continued during the intervening years.



THE PARSONS - MC CONNELL
REVISED
EFFECTIVE TEMPERATURE CHART
Fig. 173.

temperature index also fails to allow for radiation, and in areas where radiation is a factor some correction must be applied. This is generally done by lowering the effective temperature in the event of radiation from a heat source to the body, and by increasing it where heat is lost from the body by radiation to colder surfaces.

Instruments for Determining Effective Temperature.– Instruments indicating the effective temperature have been designed recently. Perhaps the simplest of these is the Bailey-Parsons *Therhumiter* which indicates the effective temperature by the revised numerical index based on humidity of 50 per cent, based on the original or basic effective temperature index.

In areas where consideration must be given to radiated sources of heat the *Thermointegrator* of Winslow and Greenburg and the *Heated-Globe thermometer* of Yaglou have been designed to include the effects of radiation.

VENTILATION AND AIR CONDITIONING

Having discussed the physical qualities of air which affect human comfort and indicated the usual methods of measuring these qualities, the real difficulty arises in the attempt to arrive at definite standards of air conditions under which groups of individuals will feel equally comfortable, because comfort after all is the individual's assessment of his environment and differs with the individual. Fortunately, exposure to extreme temperatures and humidities indoors can usually be avoided, and the maintenance of reasonably comfortable conditions can be accomplished by adequate ventilating and air conditioning methods.

Natural ventilation is satisfactory as a rule where there is provided 50 square feet of floor area and 500 cubic feet of air space per person and where effective openings in windows and skylights equal 5 per cent of the floor area. Otherwise, some mechanical means of delivering or exhausting air is necessary.

The term *air conditioning* applies to a system which, in addition to supplying and removing air mechanically, also implies the simultaneous control of temperature, humidity,

and air movement both winter and summer, and whenever necessary, the control of radiant heat and of air purity with regard to dusts, fumes, gases, and odors. The term is frequently, but incorrectly, applied to mechanical systems which accomplish but one or two of these features. An important advantage that air conditioning has over all other forms of ventilation is the exactness with which an efficient system, properly maintained and operated, can control indoor environmental atmosphere.

Effective Temperature and Control

For the average physically well adult engaged in sedentary work a temperature range between 68° and 73° F. with moderate humidity and air movement not exceeding 50 linear feet per minute will generally be found satisfactory.

In the cooperative studies previously referred to, the "effective temperature" at which the majority of the individuals felt most comfortable is represented on the "effective temperature scale" as 66° F. (on the revised scale as 70° F.). It should be noted that these experiments were conducted during the winter season. Later experiments conducted by Yaglou and Drinker at the Harvard School of Public Health* indicate that during the summer season the comfort line shifts to higher temperatures, and is represented on the scale at approximately 71° F. (on the revised scale as 76° F.). The effective temperature scale also indicates winter and summer comfort zones, represented by a range of temperatures over which an appreciable number of individuals taking part in the experiments felt comfortable. The comfort zones indicate effective temperatures deviating as much as six degrees above and below the optimum comfort temperature. The variation between winter and summer can be attributed to the important factor of acclimatization and to the difference in clothing worn during the two seasons.

The Research Laboratory of the American Society of Heating and Ventilating Engineers is continuing its research

* "The Summer Comfort Zone; Climate and Clothing," C. P. Yaglou and Philip Drinker, Journal of Industrial Hygiene, Vol. X, No. 10, p. 350 (Dec.), 1928.

work, and has conducted many studies during recent years for the purpose of ascertaining more exactly the *indoor atmospheric conditions* conducive to optimum comfort. During 1940 its Advisory Committee on Sensations of Comfort published an interim report—based on a review of the recent research studies—concerning indoor effective temperatures for summer occupancies. It was recommended that the United States be divided into four zones from north to south

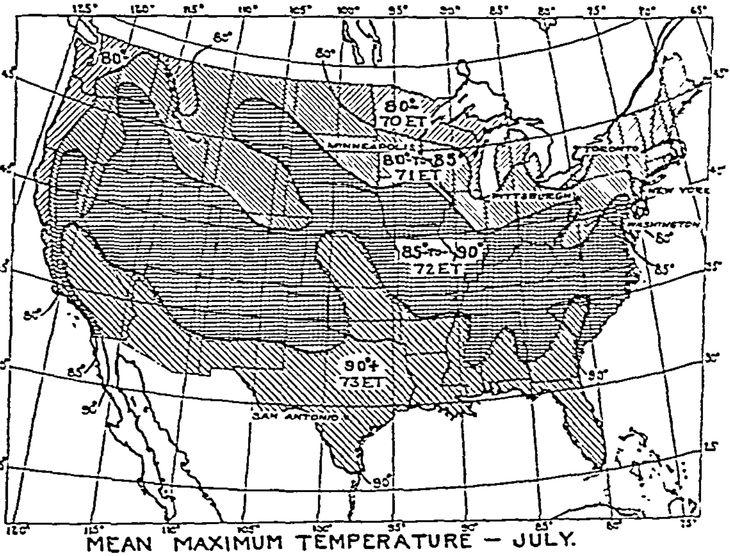


Fig. 174.—(Courtesy of American Society of Heating and Ventilating Engineers.)

embracing a range of recommended indoor "effective temperatures" from 70 to 73° F. (as shown in Fig. 174). The recommendations apply to the average modern type of building with normal walls and windows, and for long occupancy periods. It is further recommended that the relative humidity for summer comfort should not be in excess of 70 per cent, and that more satisfactory results can be obtained with lower relative humidities.

Wider Application of Air Conditioning

While ventilating methods may provide a satisfactory atmospheric environment under limited circumstances, air conditioning has a much broader application and, in many instances, is the only feasible method of sustaining a comfortable environment in large and crowded indoor areas. It is the only means by which predetermined air conditions can be brought about and maintained within narrow limits, despite variations in the weather and the degree of crowding within an enclosed space.

Air conditioning is used extensively in a variety of industries for the purpose of conditioning certain processes. The atmospheric requirements for processes, however, do not always produce comfortable conditions for the workers. In the majority of industrial plants, because of economic and other reasons, air conditioning is not employed, and ventilating methods are depended upon to provide adequate air exchange.

In the *hot industries* it may be necessary to resort to specially designed devices for providing a tolerable working environment. Local heat sources frequently can be controlled by enclosing the process and exhausting the hot air to the outside of the plant. Houghten* and his colleagues have demonstrated that workers engaged in processes requiring or resulting in hot surroundings can be protected against extreme discomfort by either directing relatively cool air at high velocity from a four-inch nozzle over the worker performing his tasks, or circulating relatively small volumes of cool air through a loose fitting garment worn by the worker. The latter method is applicable to large enclosures where comparatively few workers are engaged in hot processes which do not require the worker to move from one place to another over a large area. Where a large number of workers is engaged in a given enclosure, the indicated solution is obviously comfort cooling of the entire enclosure. Adequate control of the physical atmospheric environment in indus-

* "Local Cooling of Workers in Hot Industry," F. C. Houghten, M. B. Ferderber and Carl Gutberlet, Heating, Piping and Air Conditioning, July, 1941.

trial plants presents many special problems, the solution of which offers a challenge to the ingenuity of the engineer.

Air Purity

A second important function of the air is to provide the individual with an adequate amount of pure respirable air and to act as the vehicle for removing as quickly as possible air contaminated with the waste products of respiration. It too frequently happens, however, that the air breathed is not pure, but is contaminated with foreign materials, such as dusts, smoke, fumes, gases, and microorganisms, many of which are toxic or deleterious to the body when inhaled into the lungs.

Measures for Purifying the Air.—A number of effective measures for either removing the deleterious substances from the air, or preventing their access to the air breathed, is at our disposal. A variety of *air filters* is available which have been found effective in excluding foreign substances from the air entering occupied enclosures. The beneficial effects of filtered air on individuals suffering from hay fever, pollen-asthma, and other allergic diseases have been demonstrated with most satisfactory results.

The entrapment of air contaminated with unwanted gases, fumes, and dusts, produced by industrial processes, and its subsequent removal by means of exhaust equipment wherever it is at all feasible, is the preferred method of preventing the dispersion of these substances into the plant atmosphere. The object of *exhaust ventilation* is to produce at the point of generation of these by-products air currents of the proper magnitude and direction so as to force the polluted air into the exhaust system where it is discharged to the outdoor atmosphere. Where control of these contaminants at their source is impracticable, the exposed workers should be required to wear approved types of *respirators* for protection against the inhalation of these foreign air substances.

Other control measures applicable to harmful industrial processes include the complete enclosure of the process, the substitution of harmless or less harmful substances in the

process, increased general ventilation, good housekeeping, shop education, and medical supervision.

DEVIATIONS IN AIR COMPOSITION

In addition to air contamination with toxic or deleterious substances, the possibility of either deviations in the proportions of the normal constituent gases of the air or in air pressure must not be overlooked. Fortunately, any serious deviations need be considered only under unusual circumstances. Symptoms of *anoxemia* occur when the oxygen content of the air diminishes to less than 17 per cent. Life is endangered with a reduction of oxygen to 10 per cent. A marked decrease in the partial pressure of oxygen is encountered by aviators flying at high altitudes. Symptoms of anoxemia usually occur at altitudes around 12,000 feet unless oxygen is artificially supplied. Slight symptoms are often observed at half this altitude if ascent is sudden or the stay in the rarified air is prolonged.

An increase in air pressure occurs in compressed air work, such as is encountered within a diving suit or caisson, where the air pressure must at least equal the water pressure outside. *Compressed air illness* occurs during decompression of the worker and is due to the liberation of bubbles of gas consisting almost entirely of nitrogen into the blood and tissues of the body.

DISINFECTION OF AIR

Measures aimed at the destruction or inhibition of disease-producing bacteria in the air breathed also have been proposed during recent years. The employment of *ultraviolet radiation* as a germicide, and the use of various *chemical disinfectants* are gaining favor as adjuncts to the purification of the air. The design of the ultraviolet lamp installation to meet the requirements for adequate disinfection of an area and at the same time protect the occupants is a problem for solution by the manufacturer of the lamp.

The Medical Clinics of North America
July, 1942.

PROTECTIVE OINTMENTS AND INDUSTRIAL CLEANSERS

LOUIS SCHWARTZ, M.D.*

THE keynote of the prevention of occupational dermatitis is to keep contact of irritants with the skin at a minimum. Of first importance are totally enclosed processes; second, adequate local and general exhaust ventilation; third, protective clothing; fourth, enforcement of cleanliness; fifth, protective ointments; and sixth, the use of nonirritant industrial cleansers.

PROTECTIVE OINTMENTS

While protective ointments are low on the list of preventive measures, they are often the only available means of protection. In other instances they protect the skin from irritants which may escape into the air in spite of other preventive measures. Again, the face cannot be covered by protective clothing, and often the work must be carried on with bare hands, gloves being unsuited for work or impeding the speed of the operation. Moreover, workers dislike to wear gloves and seem to like to use protective ointments. When a protective ointment is used, the worker invariably removes it with soap and water immediately after work and so removes at the same time whatever irritants are on the skin. This adds considerably to the protection supposedly given by the ointment.

All protective ointments should have the following *properties:*

1. They should be nonirritating and nonsensitizing.
2. They should offer actual protection from the irritant.

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3. They should be of such consistency that they can be applied easily.

4. They should be easily removable after work and yet stay on while the worker is exposed.

Types

Protective applications may be divided into six classes:

1. A *simple vanishing cream* which when rubbed into the skin fills the pores with soap which facilitates the removal of soil when washing after work.

Type formula:

Stearic acid	20
Sodium carbonate	2
Glycerin	6
Water	78

Melt stearic acid; dissolve sodium carbonate in water and heat to same temperature as stearic acid. Pour hot alkali solution slowly into hot stearic acid, stirring the mixture while pouring and until cold.

2. *Ointments which leave a thin film of a resin or wax on the skin and thus prevent the irritant from touching the skin.* This class can be subdivided into (*a*) water-soluble films, and (*b*) water-insoluble films. They may be in the form of ointments, emulsions, or solutions. This class of protectives is sometimes called the "invisible glove" type.

The *water-soluble films* give some protection against solvents, such as petroleum distillates, the solvent chlorinated hydrocarbons, and water-insoluble allergens such as trinitrotoluene and tetryl. They are easily removed by water and therefore often tend to flake off as the perspiration accumulates beneath them. To counteract this action, they are sometimes mixed with fats and oils. Methyl cellulose, Irish moss, sodium silicate, karaya, quince seed, mucilage, acacia, tragacanth, casein, Elastolac (water-soluble shellac), sodium alginate, and pectin are some of the water-soluble resins that may be used for this purpose.

The second type of films includes *water-insoluble resins and waxes* used to keep out water-soluble irritants. These resins have the disadvantage of requiring a volatile solvent in order to be applied and a special cleanser must be used for their removal. Such solvents and cleansers may defat

and hence irritate the skin. Shellac and nitrocellulose are the most frequently used resins in this form of protective, and alcohol, ether, and acetone are the usual solvents. When such protective films are used it is advisable to apply an emollient such as a mixture of lanolin and cold cream to the skin after washing off the protective film. When a wax coating is applied as the invisible film, it is usually contained in a vanishing cream, and a mineral oil is used as a softening agent.

The invisible glove type of film is also a good protective against dermatitis of the face from the edges of respirators and gas masks.

Type formula—2 (*a*):

Acacia	5
Tragacanth	5
Borax	2
Water	88

Dissolve borax in hot water. Powder and mix acacia and tragacanth and dissolve in solution.

Type formula—2 (*b*):

Gum benzoin	5
Beeswax	2
Anhydrous lanolin	5
Ethyl alcohol	88

Melt and mix lanolin and beeswax and allow to cool. Dissolve gum benzoin in alcohol and then dissolve lanolin and beeswax mixture in the solution.

3. *Protective ointments which cover the skin and fill the pores with a harmless fat to repel water-soluble irritants and prevent the entrance into the pores of harmful petroleum oils, greases, and coal-tar derivatives.* Because fat solvents must act on the film of fatty ointment before they can attack the skin, this type of protective ointment also offers some protection against solvents by buffering their action on the skin. This class of ointments is difficult to remove with soap and water. Therefore some manufacturers have added synthetic wetting agents to facilitate their removal. This class is recommended against cutting oils, greases, creosote oil, pitch, excessive sunlight, and photosensitizing chemicals, especially if they contain chemical and physical light

screens. They can also be used to rub into the skin after work to lubricate and soften dry skin.

Type formula:

Anhydrous lanolin	70
Castor oil	30
Perfume q.s.	

Melt lanolin and mix in the castor oil. Perfume when cool.

4. *Protective ointments which contain a nonirritant chemical intended to detoxify the industrial irritant.* For instance, a cream to protect against alkalis may contain boric or benzoic acid intended to neutralize the alkali. The addition of an animal or vegetable fat or oil to such a cream further buffers the action of the alkali by combining with it to form a soap. A protective cream against acids may contain soap and magnesium hydroxide intended to neutralize the acid. A protective cream against such substances as poison ivy and the vesicant war gases which are detoxified by oxidation may contain a nonirritant oxidizer such as the various oxidizing peroxides, or one that gives off chlorine such as dichloramine T:

Type formula:

Magnesium carbonate	5
Talc	5
Soap	30
Lanolin	30
Castor oil	28
Duponol	2
Perfume q.s.	

Mix soap, lanolin, and castor oil. Incorporate magnesium carbonate and Duponol.

5. *Protective ointments which cause inert powders to adhere to the skin, forming a protective covering against skin irritants.* The powders may be calamine, zinc oxide, iron oxide, kieselguhr, Bentonite, and so on. The adhesive or binder may be any of the water-soluble resins used in the "invisible glove" type of cream. These ointments are of value in protecting against water-insoluble allergenic substances such as the military explosives, and against physical agents which may pierce the skin, such as sharp pieces of glass, slivers of steel, and thorns or fuzz on flowers, fruits, and vegetables.

Type formula:

Zinc oxide	5
Talc	5
Iron oxide	1
Irish moss	2
Gum benzoin	2
Water	10
Alcohol	15
Vanishing cream	60

Dissolve Irish moss in water. Dissolve benzoin in alcohol. Mix with powders and incorporate into vanishing cream.

6. *Protective applications against the photosensitizing action of the heavy coal-tar distillates, oil distillation residues, and excessive sunlight* may contain such physical light screens as menthyl salicylate, aesculin, cycloform, esculetin, menthyl benzoate, benzyl salicylate, quinine oleate, menthyl anthranilate, tannic acid, and tannates.

Type formula:

Lanolin	58
Castor oil	30
Titanium dioxide	5
Menthyl salicylate	5
Duponol	2
Perfume q.s.	

Melt lanolin and mix with castor oil. Incorporate titanium dioxide, menthyl salicylate, and Duponol.

Most of the protective creams, emulsions, and lotions on the market are combinations of these six types of creams.

Makers of industrial protective creams were requested to give information regarding the ingredients in their products. The formulas received in response to this request have been classified as follows:

COMPOSITION OF INDUSTRIAL PROTECTIVE CREAMS

Manufacturer	*Name of Product*	*Ingredients*	*Class*
West Disinfecting Co.	West Protective Cream No. 11	Stearic acid, beeswax, lanolin, benzoic acid, glycerin, borax, potassium carbonate, mineral oil, petrolatum and glycol stearate	Combination of Types 1, 2 and 3.

COMPOSITION OF INDUSTRIAL PROTECTIVE CREAMS—*Continued*

Manufacturer	*Name of Product*	*Ingredients*	*Class*
West Disinfecting Co.	West Protective Cream No. 22	Stearic acid, glycerin, borax and combined potash	Type 1.
West Disinfecting Co.	West Protective Cream No. 23	Stearic acid, spermaceti, glycerin, borax, potash, Irish moss, starch, gums, benzoic acid and perfume	Combination of Types 1, 2 and 4.
West Disinfecting Co.	West Protective Cream No. 33	Alcohol 17%, gums, Irish moss, starch, spermaceti, borax, benzoic acid	Type 2.
West Disinfecting Co.	West Protective Cream No. 44	Spermaceti, paraffin, glycol stearate, lanolin, castor oil, soap, borax and benzoic acid	Combination of Types 2 and 3.
West Disinfecting Co.	West Protective Cream No. 55	Castor oil, olive oil, paraffin, lanolin and glycol stearate	Combination of Types 2 and 3.
West Disinfecting Co.	West Protective Cream No. 66	Lanolin, glycerin, zinc oxide, glycol stearate, Duponol, spermaceti and benzoic acid	Combination of Types 3 and 5.
West Disinfecting Co.	West Protective Cream No. 77	Cetyl alcohol, stearyl alcohol, ceresin, castor oil, mineral oil, sodium lauryl sulfate, sodium perborate and perfume	Combination of Types 3 and 4
West Disinfecting Co.	West Protective Cream No. 88	Castor oil, olive oil, lanolin, diglycol stearate, paraffin, titanium oxide, Duponol and menthyl salicylate	Combination of Types 3 and 6.
Milburn Co.	Ply No. 1	Basic emulsion, stearic acid (vanishing cream), and vegetable gum	Combination of Types 1 and 2.
Milburn Co.	Ply No. 2	Same as Ply No. 1 plus addition of water-soluble synthetic resin	Combination of Types 1 and 2.
Milburn Co.	Ply No. 6	Lanolin, petrolatum (violet ray treated), zinc oxide and corn starch	Combination of Types 3 and 5.

COMPOSITION OF INDUSTRIAL PROTECTIVE CREAMS—*Continued*

Manufacturer	*Name of Product*	*Ingredients*	*Class*
Milburn Co.	Ply No. 6-A	Lanolin, petrolatum (violet ray treated), boric acid and corn starch	Combination of Types 3 and 4.
Milburn Co.	Ply No. 9	Aqueous solution of vegetable gums, sodium and potassium phosphate	Type 2.
Milburn Co.	Ply No. 9-A	Similar to Ply No. 9 in cream form	Type 2.
Kolar Laboratories	Hand-I-Septic	Aliphatic hydrocarbons, U.S.P. cosmetic oil, soluble cellulose, sodium alkyl sulfate, chlorthymol, methyl salicylate, glycerin, silicates and titanium dioxide	Combination of Types 2, 5 and 6.
Davis Co, Inc.	Eco Protective Cream No. 1	Gum arabic, Ivory soap, lanolin, perfume and water	Combination of Types 2 and 3.
Davis Co., Inc.	Eco Protective Cream No. 2	Stearic acid, cocoa butter, carbitol, glycerin, borax, potassium hydroxide, cetyl alcohol, perfume and water	Combination of Types 1 and 3.
Dr. George W. Fiero, University of Buffalo Sold by Dermal Products	Protective against water - soluble allergens and gasoline and oil allergenic substances	Calamine and film of water-repellent hydrogenated castor oil	Combination of Types 3 and 5.
H. Kirk White & Co.	Dermo Cream	Stearic acid, lanolin anhydrous, borax, triethanolamine, Methocel solution, carbitol, terpineol, cresol and Naccanol	Combination of Types 1 and 2.
E. I. du Pont de Nemours & Co.	Pro-Tek	"Invisible glove" type	Type 2.
Wambaugh Chemical Co.	I-Heal-U Ointment	Lanolin, picric acid and perfume	Combination of Types 3 and 4.

COMPOSITION OF INDUSTRIAL PROTECTIVE CREAMS—*Continued*

Manufacturer	*Name of Product*	*Ingredients*	*Class*
Wambaugh Chemical Co.	Nickel-Itch Ointment	Petrolatum, calamine, zinc oxide, glycerin and phenol	Type 5.
Wambaugh Chemical Co.	Chrome Ointment	Lanolin, petrolatum and balm of Gilead	Type 3.
Duke Laboratories	Tecto	Emulsion of water in aliphatic hydrocarbon fats. Esters of alcohols of cholesterols	Type 3.
Prack Laboratories, Inc.	Practi-Kreme	Water, glycerin, vegetable fat, animal fat, vegetable oil, vegetable oil base wetting agent, bland soap, vegetable color and perfume	Combination protective and cleanser. Type 3.
Prack Laboratories, Inc.	Prack Formula 33	Petrolatum, paraffin, soap stock oil, resin and titanium oxide	Combination of Types 2, 3 and 5. (Waterproof protection suitable for allergens. Must be removed with very hot water and Practi-Kreme.)
Standard Safety Equipment Co.	Economy Skin Shield	Natural gums, glycerin and neutral detergent	Type 2.
Standard Safety Equipment Co.	WR-318	Wax emulsion to protect against water-soluble substances	Type 2 (b).
Doak Co.	Sav-Skin 1	Zinc hydroxide, quinine oleate, heavy emulsion of vegetable oils and lecithin	Combination of Types 3, 4 and 6.
Doak Co.	Sav-Skin 2	Zinc oxide, iron oxide, resin and cream base	Type 5.
Doster & Co.	Texkin	Water, glycerin, sodium silicate, sodium stearate (chips), gum tragacanth solution, color and Limonene	Type 2 (a).

INDUSTRIAL SKIN CLEANSERS

Personal cleanliness is one of the most important preventives of occupational dermatitis. Therefore, the use of suitable cleansers should be encouraged. In an effort to remove speedily and completely tenacious soil or dyes from the skin, workers often use harsh cleansers, such as strong abrasive soaps with high alkaline content and powerful solvents. Dermatitis resulting from this harsh treatment is of frequent occurrence, and such irritations of the skin are sometimes mistakenly attributed to the substances handled while working.

Physical and Chemical Action of Detergents

In order to know what detergents are best adapted for use as industrial skin cleansers, something of the chemical and physical properties by means of which detergents remove soil from the skin should be understood.

There are various theories regarding the action of soaps as cleansers. Among others, the following may be mentioned:

1. Soap solutions emulsify oils: the alkali set free when soap dissolves emulsifies the fatty material adhering to soil and enables the solution to carry away the loosened particles.
2. The alkali liberated when soap dissolves acts as a solvent for greasy matter on the surface to be cleaned.
3. By increasing surface activity, and by wetting and penetrating oily substances, the alkali loosens dirt and soil which are washed away in solution.
4. The soap acts as a lubricant and allows dirt to be rubbed off easily.
5. The hydrolysis of soap forms colloidal acid soap, which in turn forms colloidal absorption compounds with the dirt.

There are various *chemicals* which when added to soap increase the detergent action. Some of these aid the action of soap by increasing the free alkali content. Such are sodium carbonate, sodium silicate, sodium metasilicate, trisodium phosphate, disodium phosphate, sodium hexametaphosphate, and trisodium borate.

Some assist by softening the hard waters and permitting the soap to act. Such are the water softeners—sodium hexametaphosphate (Calgon); chemical neutral metaphosphate

(Paratex); tetrasodium phosphate (Phosphotex); and sodium tetraphosphate (Quadrafor).

Some assist by increasing the wetting power and surface activity of the soap solution. Such are the synthetic wetting agents.

Wetting Agents

In order that dirt may be removed easily from the skin, both must be wetted by the cleanser. Wetting agents lower the surface tension of liquids, enabling them to spread over the surface and penetrate into the pores. They also act as "surface active" agents, thus enabling the solution to penetrate oily or waxy films making the dirt easily removable. The molecules of wetting agents are composed of two essential parts, one part attaches itself to the water molecule and the other part attaches itself to the oil molecule. In this manner the molecule of the wetting agent brings together the otherwise immiscible water and oil molecules. Sulfonated castor oil and the synthetic wetting agents act in this manner.

The principal *synthetic wetting agents* are:

1. Sodium salts of the higher alcohol sulfosuccinates, of which Aerosol O T is a representative.
2. The long chain of alcohol sulfates, of which Duponol is a representative.
3. The alkyl aryl sulfonates, of which Santomerse is a representative.
4. The alkyl naphthalene sulfonates, of which Alkanol is a representative.

The principal wetting agents and detergents are listed below:

SYNTHETIC WETTING AGENTS AND DETERGENTS

Name	*Use*	*Chemical Nature*	*Manufacturer*
Alivol	Wetting	Alkyl argyl sulfonate	Westwood Pharm. Co.
Alkanol B	Wetting	Sodium alkyl naphthalene sulfonate	du Pont de Nemours & Co.
Alkanol H G	Wetting	Sodium aklyl naphthalene sulfonate	du Pont de Nemours & Co.
Alkanol S A	Wetting	Sodium alkyl naphthalene sulfonate	du Pont de Nemours & Co.
Alkanol W X N	Wetting and rewetting	Sodium hydrocarbon sulfonate	du Pont de Nemours & Co.

SYNTHETIC WETTING AGENTS AND DETERGENTS—*Continued*

Name	*Use*	*Chemical Nature*	*Manufacturer*
Arctic Syntex M Flakes	Wetting and detergent	Sodium salt of a sulfated fatty ester	Colgate-Palmolive Peet Co.
Arctic Syntex M Liquid	Wetting and detergent	Ammonium salt of sulfated fatty ester	Colgate-Palmolive Peet Co.
Aerosol O T	Wetting	Di-octyl sodium sulfosuccinate	Amer. Cyanamid & Chemical Corp.
Areskap	Wetting and detergent	Sodium alkyl aryl sulfonate	Monsanto Chemical Co.
Arylene	Wetting and penetrant	Alkyl naphthalene sulfonate	Hart Products Corp.
Cerfak	Wetting and detergent	Alkyl aromatic sulfonate	E. F. Houghton & Co.
Chenol Concentrate	Detergent	Amino condensate	Burkart-Schier Chemical Co.
Cyclopon A and G A	Detergent	Fatty acid amide alkyl sulfonate	General Dyestuff Corp.
Deceresol A S	Wetting	Alkyl aryl sulfonate	American Cyanamid & Chemical Corp
Deceresol A Y	Wetting	Sodium salt of diamyl-sulfosuccinate	American Cyanamid & Chemical Corp.
Deceresol M A	Wetting	Sodium salt of dimethyl-sulfosuccinate	American Cyanamid & Chemical Corp.
Deceresol O S	Wetting	Sodium salt of diisopropyl-naphthalene sulfonic acid	American Cyanamid & Chemical Corp.
Deceresol O T	Wetting	Sodium salt of dioctyl-sulfosuccinate	American Cyanamid & Chemical Corp.
Diglycol Laurate S	Wetting and penetrant	Lauric acid ester of diethylene glycol	Glyco Products Co.
Duponol P C	Wetting and emulsifying	Long chain alcohol sulfate	du Pont de Nemours & Co.
Gardinol L S Flake	Wetting and detergent	Sodium sulfate of technical oleyl alcohol	du Pont de Nemours & Co.
Gardinol W A	Wetting and detergent	Sodium sulfate of technical lauryl alcohol	du Pont de Nemours & Co.
Igepon T	Wetting	Condensation product of fatty acid with amino sulfonic acid ($C_{17}H_{33}$.-CO.NCH_3.C_2H_4.SO_3Na)	General Dyestuff Corp.

SYNTHETIC WETTING AGENTS AND DETERGENTS—*Continued*

Name	*Use*	*Chemical Nature*	*Manufacturer*
Intramine	Wetting and detergent	Sodium salt of sulfonated lauryl myristic collamide	Synthetic Chemicals Corp.
Invadine N	Wetting	Sodium alkyl naphthalene sulfonate	Ciba Co.
K-25	Wetting and detergent	High molecular amine condensation product	E. F. Houghton & Co.
Lanitol	Wetting	Sodium alkyl naphthalene sulfonate	Arkansas Co.
Maprofix powder	Detergent	Sodium borosulfate of technical cetyl to octadecenyl alcohol	Onyx Oil & Chem. Co.
Mapromol powder	Wetting	Sodium borosulfate of technical octadecenyl alcohol	Richards Chemical Works
Merpol B	Wetting and detergent	Long chain alcohol sulfate product	du Pont de Nemours Co.
Modinal Paste E S	Wetting and detergent	Long chain alcohol sulfate product	du Pont de Nemours & Co.
Modinal Paste E S	Wetting and detergent	Sodium sulfate of technical octadecenyl alcohol	Procter & Gamble, Inc.
N-25	Wetting and detergent	High mol. weight amine condensation product	E. F. Houghton & Co.
Nacconol L A L	Wetting	Sodium lauryl sulfoacetate	National Aniline & Chemical Co.
Nacconol N R	Wetting and detergent	Sodium alkyl aryl sulfonate	National Aniline & Chemical Co.
Nacconol F S N O	Wetting and detergent	Sodium alkyl aryl sulfonate	National Aniline & Chemical Co.
Neomerpin	Wetting and detergent	Sodium alkyl naphthalene sulfonate	du Pont de Nemours & Co.
N O P C O 1086 B	Wetting	Ester sulfonate	National Oil Products
Novonacco	Wetting	Modified sodium alkyl naphthalene sulfonate	National Aniline & Chemical Co.
Nycolene-3	Wetting	Alkyl aryl sulfonate	New York Color & Chemical Co.
Oranap	Wetting and penetrant	Sodium alkyl naphthalene sulfonate	Jacques Wolf & Co.
Penetrolin A Conc.	Wetting	Sodium alkyl naphthalene sulfonate	Arkansas Co
Permeko	Wetting	Sodium alkyl naphthalene sulfonate	John Campbell & Co.
Retravon W	Detergent	Sodium benzimidiazol-sulfonate	Ciba Co.
Santol T	Wetting	Sulfonated aryl alcohol	Charlotte Chemical Laboratories

SYNTHETIC WETTING AGENTS AND DETERGENTS—*Continued*

Name	*Use*	*Chemical Nature*	*Manufacturer*
Santomerse	Wetting and detergent	Sodium alkyl aryl sulfonate	Monsanto Chemical Co.
Solvadine G	Detergent	Aryl alkyl sulfonate	Ciba Co.
Solvadine A L	Detergent	Aryl alkyl sulfonate	Ciba Co.
Solvadine N C	Wetting	Sodium salt of the sulfonic acid of a petroleum hydrocarbon	Ciba Co.
Sulfanole	Detergent	Sulfonated fatty amide	Warwick Chemical Co.
Sulfatex	Detergent	Sodium alkyl aryl sulfonate	L. Sonneborn Sons
Tergavon C & A	Detergent	Sulfated fatty esters	Ciba Co.
Tetranol	Wetting	Highly sulfonated fatty ester	Arkansas Co.
Titawet I T	Wetting	Sodium alkyl naphthalene sulfonate	Titan Chemical Products, Inc.
Triton N E	Wetting and detergent	Polymerized organic alcohol with ether linkages	Rohm & Haas Co., Inc.
Triton W-30	Wetting	Sulfated ether	Rohm & Haas Co., Inc.
Warcosol Paste	Wetting	Sodium alkyl naphthalene sulfonate	Warwick Chemical Co.
Warcosol S97	Wetting	Sulfated aliphatic hydrocarbon in pine oil	Warwick Chemical Co.
Xynomine Powder	Wetting and detergent	Sulfated boro amide ester of aliphatic compounds	Onyx Oil & Chemical Co.

Some synthetic wetting agents also have detergent and water softening powers and will act in hard or soft water, acid, alkaline, or neutral solutions.

COMBINATION WETTING AGENTS AND DETERGENTS WHICH MAY BE USED AS SKIN CLEANSERS

Name	*Manufacturer*
Triton N E	Rohm & Haas Co., Inc.
Xynomine Powder	Onyx Oil & Chemical Co.
Gardinol L S & W A	du Pont de Nemours & Co.
Cerfak	E. F. Houghton & Co.
Arctic Syntex M	Colgate-Palmolive Peet Co.
Igepon T	General Dyestuff Corp.
Intramine	Synthetic Chemicals Corp.
K-25	E. F. Houghton & Co.
Merpol B	du Pont de Nemours & Co.
Modinal Paste E S	du Pont de Nemours & Co.
N-25	E. F. Houghton & Co.
Nacconol N R	National Aniline & Chemical Co.
Santomerse	Monsanto Chemical Co.
Duponol P C	du Pont de Nemours & Co.

Solvents

Organic solvents are sometimes added to soap to increase its solvent power and aid in removing fats, oils, greases, and dyes from the skin. Soaps used to remove indelible inks and dyes often contain carbon tetrachloride, naphtha, dioxane, and other hydrocarbon solvents. Bentonite or any other colloidal clay which has good detergent properties in itself is sometimes added to some soaps as a filler.

Action of Detergents on the Skin

Soaps and other detergents have a physical and chemical action on the skin itself. Alkalis dissolve the keratin and emulsify sebum, cholesterol, and skin fats. Neutral or acid wetting agents, detergents, and solvents act in a similar manner, except that they do not dissolve the keratin. Hence, the prolonged action of strong soaps, wetting agents, alkalis, and solvents on the skin will result in dermatitis, the dermatitis occurring more quickly on dry skins than on oily or normal skins.

In addition to this, some skins may become allergic to alkalis, certain fatty acids, their salts, the synthetic detergents, wetting agents, or organic solvents. All these facts must be considered in choosing the ingredients of a particular cleanser.

The Requirements of an Industrial Cleanser

The requirements of a *normal* industrial cleanser are as follows:

1. It should be freely soluble in hard, soft, cold, or hot water.
2. It should remove fats, oils, and other soil without harming the skin.
3. It should not extract from the skin its natural fats and oils.
4. It should not contain harsh abrasives or irritant scrubbers which not only will injure the skin, but may also clog the plumbing.
5. It should be handy to use if in cake form, or flow easily through soap dispensers if in granulated or powder form.
6. It should not deteriorate or become insect infested.

In order to meet these requirements, a normal industrial cleanser for general use should consist of a superfatted neutral toilet soap, containing a wetting agent or synthetic detergent, and a soft scrubber which softens or dissolves in water and does not clog the plumbing. It should contain a minimum of free alkali, and have a pH of 10 or less in a 1 per cent solution. It should contain no silica, quartz, pumice, or feldspar, nor any rosin fillers or organic solvents.

Type formula for an industrial skin cleanser for general use:

Neutral toilet soap	30
Colloidal clay (Bentonite or Kieselguhr)	30
Santomerse (or other synthetic detergent)	10
Lanolin	5
Perfume	1

Mix colloidal clay and Santomerse. Heat soap and lanolin, and mix with the above. This may be pressed into cake form, or 25 parts of corn meal may be added to make up 100 parts and the mixture then made into a powdered soap. A mixture of equal parts of potassium-coconut oil soap and sulfonated castor oil to which 1 per cent of a synthetic detergent is added makes a good liquid cleanser.

Soaps for industrial cleansers should be sodium or potassium salts of stearic, palmitic, or oleic acids. Colloidal clay may be added because it is a harmless product which aids emulsification. In localities where the water is hard, water softeners or the synthetic wetting agents and detergents should be added to the soap. When it is necessary to remove tenacious oils or greases from the skin, the addition of ground corn meal or other soft cereal for a scrubber will aid the detergent action.

If the soil on the skin is difficult to remove without excessive scrubbing which may injure the skin, it may be necessary to add one or more of the *alkalis*, such as trisodium phosphate, to the cleanser. When this is done, the soap should be superfatted with lanolin to buffer the action of the alkali on the skin, and then lanolin should be rubbed into the skin after the cleanser is used.

Although *lathering* does not necessarily add to the detergent powers of a cleanser, yet it is a property which workers desire. Coconut oil soaps lather well. Sulfonated castor oil (Turkey red oil) increases the lathering of soap. Moderate

amounts of alkali, colloidal clay, and perchlorethylene, when added to soap, also increase lathering.

Cleansers for Soap-sensitive Workers.—Workers who are soap- or alkali-sensitive or who already have chronic eczemas or dry fissured skins from the use of ordinary industrial cleansers should be provided with cleansers other than soaps. This also applies to workers who are exposed to the organic solvents, cutting and other petroleum oils, all of which defat the skin.

Such cleansers can be made in solid cake form from mixtures of synthetic detergents, with colloidal clay, kieselguhr, or meerschaum. Lanolin may be added to the cleanser for emollient purposes.

Suggested formula:

Nacconol (or Santomerse, Igepon or Duponol)	20
Lanolin	3
Colloidal clay	76
Perfume	1

Mix and press into cakes of suitable size.

Such cleansers can also be had in liquid form. Suggested formula:

Neutral sulfonated castor oil	97
Pure castor oil	1
Santomerse (or other detergent)	2

Cleansers to Remove Hectograph or Indelible Inks.—Special cleansers are made to remove the stains of indelible inks from the skin. Such cleansers usually consist of soap, a wetting agent, added alkali, and an organic solvent, such as carbon tetrachloride, naphtha, or dioxane. They can be made in liquid form or in the form of a paste. In the latter form they may contain a scrubber.

A suggested cleanser paste for the removal of hectograph or indelible inks is as follows:

Soap	30
Sulfonated castor oil	16
Synthetic detergent	20
Trisodium phosphate	4
Dioxane	20
Colloidal clay	10

The use of this paste should be followed by rubbing into the skin a mixture of lanolin and cold cream as an emollient.

Cleanser to Remove the Stains of Dyes.—To remove the stains of dyes, the hands can be soaked in a 1:500 solution of potassium permanganate for five minutes, and then in a solution of sodium bisulfite 1:100 until the stain of the permanganate is removed. The hands should then be washed with a superfatted soap, dried, and a mixture of lanolin and cold cream, equal parts, rubbed into the skin.

Ingredients in Various Industrial Cleansers

In order to enable the physician to estimate the value of the various industrial cleansers and their suitability for use by workers with normal, oily, dry, or inflamed skins, manufacturers of such cleansers were asked for the ingredients in their products. Information received is tabulated below. From this table an industrial physician or safety director can intelligently choose the cleanser best suited to the needs of the workers under his care.

COMPOSITION OF VARIOUS INDUSTRIAL SKIN CLEANSERS

Manufacturer	*Name of Cleanser*	*Ingredients*	*Remarks*
Lightfoot-Schultz Co.	La Grace	Vegetable oil soaps, synthetic wetting agent, sulfonated oils and vegetable scrubber	Good powdered soap cleanser
C. B. Dolge Co.	Handeez	Toilet soap, sodium metaphosphate and cornmeal	Alkaline powdered soap
G. H. Packwood Co.	Pax Heavy Duty Cleanser	Anhydrous soap, lanolin, castor oil, tetra-sodium pyrophosphate, metaphosphate and cornmeal	Superfatted alkaline powdered cleanser
G. H. Packwood Co.	Pax Hyspeed Cleanser	Anhydrous soap, alkaline salts and vegetable meals	Alkaline powdered cleanser
G. H. Packwood Co.	Pax Light Duty Cleanser	Anhydrous soap and bland oils	Superfatted soap
G. H. Packwood Co.	Pax Officesoap	Anhydrous soap	
Dermal Products	Dermalav	Sulfated hydrogenated castor oil, diethylene glycol, monostearate and white petrolatum	Soapless cleanser in cases of dermatitis

COMPOSITION OF VARIOUS INDUSTRIAL SKIN CLEANSERS—*Continued*

Manufacturer	*Name of Cleanser*	*Ingredients*	*Remarks*
H. Kirk White & Co.	Miner's Special Liquid Soap	Coconut oil soft soap, methyl cellulose, sulfonated castor oil and oils of citronella and sassafras	Good liquid cleanser
H. Kirk White & Co.	So White Hand Cleanser	Soap powder, sodium carbonate, trisodium phosphate, bicarbonate of sodium, sodium bisulfite, chit of wheat and corn, germ of wheat and corn and oils of citronella and sassafras	Strong cleanser; alkaline; powdered
Standard Mailing Machines Co.	Standard Cleansing Cream	Stearic acid cream, soap, oil and organic solvent	Cream to remove hectograph ink
Sugar Beet Products Co.	SBS-11 Industrial Skin Cleanser	Wetting agent, tetra-sodium ryrophosphate, olive oil soap, palm oil soap, pine oil soap, sodium sesqui carbonate, trisodium phosphate, pine oil treated cornmeal and bentonite	Strong cleanser; alkaline; powdered
West Disinfecting Co.	Lan O Kleen	Sodium soap, lanolin, borax, trisodium phosphate, cornmeal	A superfatted alkaline powdered cleanser
West Disinfecting Co.	Sulpho Hand Cleaner	Sulfonated castor oil, wetting agent and detergent trisodium phosphate	A good soapless cleanser for the removal of oils and greases; may be used for dry skins and dermatitis
Pacific Coast Borax Co.	Boraxo	Anhydrous soap and borax	A mild alkaline powdered cleanser

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EFFECTS OF HIGH PRESSURES; PREVENTION AND TREATMENT OF COMPRESSED AIR ILLNESS*

ALBERT R. BEHNKE, Jr., M.D.†

THE fundamental studies of Paul Bert,[1] Heller, Mager, and von Schrötter,[2] and Boycott, Damant, and Haldane,[3] as well as the vast body of experience derived from tunneling operations particularly in New York State, have given us a survey of the methods underlying the prevention and treatment of compressed air illness.

During the past ten years systematic research has been conducted at the Harvard School of Public Health and at the Experimental Diving Unit, Navy Yard, Washington, D.C., leading to (*a*) the development of a highly effective method of treating compressed air illness utilizing oxygen, (*b*) the employment of helium to make possible deep-sea diving in excess of 400 feet, (*c*) a better knowledge of decompression based upon quantitative studies, and upon long exposures in compressed air, and (*d*) a specific method for testing personnel with reference to susceptibility to compressed air illness.

Recently a great deal of attention has been paid to traumatic injury of the ear as a result of pressure variation, and to lesions in bones and joints looked upon by some authors as a specific complication of compressed air illness.

Mention must be made also of the identical symptoms associated with caisson disease that have been elicited during rapid ascent in aircraft and in numerous rapid decompressions to simulated altitudes of and above 30,000 feet in the low pressure chamber.

If a better perspective is to be obtained of the principles underlying the prevention and treatment of compressed air illness, consideration should be given to recent studies in the

* The contents of this paper are not to be regarded as an official expression of the Navy Department.

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low pressure chamber which have shed new light on perennial problems.

PHYSIOLOGIC EFFECTS OF PRESSURE

Primary Pressure Phenomena

Pressure *per se* in the range that concerns us is apparently without physiologic effect provided that equalization of pressure is effected without trauma in sinal and aural spaces. A pressure of 240 pounds per square inch can be applied to the body of a diver, or the pressure can be decreased to 2 pounds per square inch in the case of the aviator without demonstrable injury.

If, on the other hand, the openings of air spaces in the ear and sinuses are occluded, then slight pressure variations in the range of 1 to 2 pounds (50 to 100 mm. Hg) per square inch elicit painful response and induce congestion, edema, and hemorrhage in the affected tissues. The cause of the occluded orifices is almost invariably related to chronic or acute infection of the nasopharynx. In the field of aviation the term *aero-otitis media* has been applied by Armstrong and Heim[4] to the traumatic changes which are also typical of the injury produced in caissons.

Temporary impairment of hearing is associated with the trauma, but a rapid spontaneous resolution of all symptoms takes place over a period of several days. The evidence at hand indicates that *pressure trauma* does not cause deafness. Moreover, the complications of suppurative otitis media and pansinusitis are rare in my experience if individuals stay out of water. The pressure trauma, however, appears to create a favorable condition for the growth of pathogenic organisms. Immediate exemption of individuals harboring infection of the nasopharynx from further pressure exposure has undoubtedly kept our complications minimal.

Requarth[5] observed that suppuration in the middle ear occurred in twelve out of 400 caisson workers complaining of pressure trauma and with the exception of a small percentage of men infection was present in the respiratory tract. Helium inhalation was of some value in alleviating symptoms but the evidence is not conclusive.

Divers with occluded eustachian tubes show about the same resistance to pressure increase irrespective of whether the atmosphere is air or a helium-oxygen mixture. It is not likely that helium penetrates the occluded tube faster than nitrogen, but possibly there is a more rapid diffusion of helium into the blocked space by way of the circulating blood.

Effects of Increased Partial Pressure of Gases

The more important physiologic phenomena incident to changes in pressure are related to the property possessed by gases of diffusing into the body when the atmospheric pressure is increased, and to the difficulty in their removal when the pressure is subsequently lowered.

Nitrogen Absorption and Elimination Curve.—The manner in which atmospheric nitrogen diffuses into or out of the body by means of the circulating blood is indicated by the graph shown in Fig. 175. The values represented on the graph were obtained by rendering the body free of dissolved nitrogen during the inhalation of oxygen. From nine to twelve hours are required for complete desaturation as far as can be determined by measurements but considerable variability is to be expected on the basis of variation in fat content of different individuals.

The substances in the body absorbing nitrogen are the fluids and the fat, in the ratio of 1 to 5. Hemoglobin also absorbs a small quantity of nitrogen. Since bone marrow contains about 90 per cent lipid substance and the spinal cord about 27 per cent, the nitrogen uptake by these tissues is of great importance.

Exercise increases the rate of gas elimination. However, the value of exercise is chiefly during the first thirty minutes when the inert gas is diffusing from body fluids. Exercise probably does not greatly influence the elimination of inert gas from the fat depots of the body.

At each atmosphere of increased pressure the absorption of nitrogen will follow the curve (Fig. 175), and the quantity absorbed will be a simple multiple of pressure corrected for the time of exposure.

Physiologic Reactions Associated with the Inhalation and Absorption of Nitrogen.—Beginning at a pressure of 4 atmospheres nitrogen acts as a *narcotic substance* to depress neuromuscular activity. At a pressure in excess of 10 atmospheres, consciousness may be lost. This remarkable property of nitrogen is consistent with the Meyer-Overton hypothesis relating narcotic action to solubility in lipid substances of the central nervous system.

The *substitution of helium* for nitrogen abolishes or renders negligible the narcotic effects of pressure, and an individual

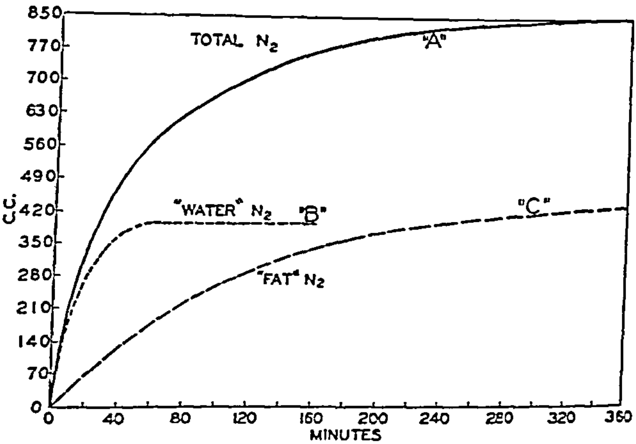


Fig. 175.—Solid line shows nitrogen elimination from a young lean man weighing about 60 kilograms. The nitrogen in the body is soluble in fat and fluids. The elimination or absorption of this nitrogen with changes in barometric pressure is represented by the hypothetical, broken-line curves on the graph. (Am. J. Physiol., *114:* 138, 1935.)

breathing a helium-oxygen mixture feels nearly as well at a pressure of 16 atmospheres as he does breathing air at normal barometric pressure.

Resistance to the inhalation of compressed air is increased roughly in proportion to the square root of the density. In the diving suit or pressure chamber up to 10 atmospheres the increased resistance is scarcely perceptible to the healthy individual. However, if respiratory appliances are worn, the increased weight of the air may prove to be a limiting factor in their use.

By contrast, *inhalation of oxygen* is effortless in the low pressure chamber at simulated altitudes of 30,000 feet. The absence also of the nitrogen pressure effect and the ease with which any symptoms of aeroembolism may be treated make activity in the low pressure chamber a matter of ease compared with the impediments encountered in high pressure atmospheres.

Increased humidity accompanying the introduction of air under pressure is due to the concomitant rise in temperature, since the capacity of air to hold moisture is a function of temperature and not of pressure. High temperature combined with the high humidity have brought about debilitating fatigue during prolonged exposure in compressed air.

Reactions Associated with High Pressure of Oxygen

The increased partial pressure of oxygen in compressed air is capable of producing pulmonary damage. F. J. C. Smith and his associates[6] found that at a pressure of 4 atmospheres, partial pressure of oxygen equivalent to 83.6 per cent of one atmosphere, adult rats developed active hyperemia and acute edema of the lungs with a mortality of 13 per cent in three days. In the lower animals there is no question as to the toxic effects of oxygen pressure of about 70 per cent of one atmosphere. *Prolonged residence in compressed air then is limited to a pressure of about 3 atmospheres absolute.*

In the Navy an important advance in the field of diving has been the employment of oxygen for the prevention and treatment of compressed air illness. During rescue and salvage operations connected with the *U.S.S. Squalus* disaster, the administration of oxygen constituted a life-saving measure. It is important, therefore, to know man's tolerance to the inhalation of pure oxygen.

Tolerance to Inhalation of Pure Oxygen.—At *sea-level pressure* the period of time that pure oxygen can be safely breathed is a matter of controversy. Although the tolerance of the anoxemic patient may be greater than that of the healthy individual, we find that healthy men frequently do not tolerate the inhalation of pure oxygen continuously for periods in excess of seven hours. In recent tests the time has

been extended to seventeen hours but there are some individuals who are sensitive to oxygen and one man developed manifestations of allergy. Irritability is a common symptom. It should be pointed out that periods of intermission when air is breathed, or a decrease in the percentage of inhaled oxygen greatly extends the tolerance time.

At a *pressure of 3 atmospheres* pure oxygen can be inhaled for a period of three hours. Symptoms indicative of pulmonary irritation do not arise but during the fourth hour of inhalation there may occur a rise in blood pressure, increase in pulse rate, and a contraction of the visual fields. *Pallor* may be extreme. Periodic waves of *nausea* constitute the most common subjective manifestation of oxygen toxicity. In diving operations, therefore, the working pressure for oxygen is limited to two and one half atmospheres.

At a *pressure of 4 atmospheres* oxygen usually can be safely breathed by men *at rest* for a period of thirty to forty-five minutes. In excess of this period convulsive seizures or syncope may occur. While the nervous manifestations of oxygen toxicity are alarming, apparently complete recovery follows when air is again inhaled.

If pure oxygen is inhaled during *exercise* at 3 atmospheres pressure, the tolerance time is greatly reduced. Pedalling a bicycle at a rate sufficient to increase normal oxygen consumption three-fold limited the inhalation of oxygen to a period of about twenty minutes. This exercise test is valuable in determining the oxygen tolerance of a given individual. It also provides a clue as to the nature of oxygen poisoning.

Fortunately these limits defining man's tolerance for oxygen permit this gas to form an essential part in the prevention and treatment of compressed air illness.

The Effect of Carbon Dioxide

Carbon dioxide enhances the toxicity of oxygen and the narcotic effect of nitrogen. In the diver's helmet the percentage of carbon dioxide must be reduced to a minimum. It was undoubtedly an increased percentage of carbon dioxide in the diving helmet that rendered operation in compressed

air impracticable in connection with the salvage of the *U.S.S. Squalus.*[7]

In combination with high oxygen pressures, carbon dioxide has been responsible for loss of consciousness on several occasions followed by a maniacal type of reaction during the recovery of consciousness in the recompression chamber. On one occasion similar symptoms could be attributed to the effect of carbon dioxide itself.

With respect to work in compressed air a higher incidence of "bends" has been associated with a rise in the carbon dioxide level. At atmospheric pressure a percentage of 1.5 is well tolerated by slightly active individuals for periods of forty-eight hours. Higher percentages invariably cause headache. At higher pressures the percentage must be correspondingly reduced so that the partial pressure does not exceed 1.5 per cent of 1 atmosphere. In the diver's helmet the attempt is made to reduce the partial pressure of carbon dioxide to a value equivalent to 0.1 or 0.2 per cent of one atmosphere.

The Value of Helium

A notable advance in deep-sea diving making possible the salvage of the *U.S.S. Squalus* at a depth of 240 feet was the introduction of helium as a substitute for nitrogen in the diver's gas supply. Essentially practical diving operations have been increased from the physiologist's point of view from a depth of 150 feet to a depth of 500 feet.

The advantage of using helium is derived from its properties which (*a*) render negligible the narcotic effect of nitrogen, and (*b*) reduce solubility in fat compared with nitrogen in ratio of 1 to 4.5. The importance of this second property will be discussed in a subsequent paragraph.

COMPRESSED AIR ILLNESS

The Problem.—Rapid decompression after sufficient exposure in compressed air may give rise to the formation in the blood stream of bubbles composed chiefly of nitrogen together with small quantities of water vapor, carbon dioxide, and some oxygen. These emboli deprive tissue of normal blood supply to elicit characteristic symptoms of pain, asphyxia, and occasionally paralysis. The symptoms occur

either singly or in combination and indicate that the areas for bubble formation and accumulation are veins, right chambers of the heart, pulmonary vascular bed, spinal cord, and the bones, especially bone marrow. Treatment aims at the removal of the emboli in the shortest possible time in order to minimize injury particularly with reference to the spinal cord and right ventricle.

Etiology, Symptomatology

Until further proof is adduced there is no reason to accept any other explanation for the cause of compressed air illness than Paul Bert's classic observation embracing the theory of nitrogen embolism.

IN ANIMALS.—Swindle[8] describes agglutination of the erythrocytes incident to rapid decompression. End[9] confirms this observation in lower animals. In anesthetized dogs rapidly decompressed from high pressure atmospheres, one observes that gas bubbles move through arteries and veins. As the number and size of the bubbles increase, blood flow slows down and ceases entirely.

Embolic interference with blood flow elicits a pathognomonic triad of symptoms consisting of *rapid respiration, fall in blood pressure,* and *decrease in pulse rate.* These symptoms are primarily attributed to asphyxia arising from massive pulmonary embolism.[10] This conclusion is substantiated by analyses of oxygen content of blood showing a marked reduction in the percentage saturation of both arterial and venous hemoglobin (Table 1[11]).

The most remarkable finding, however, was the occurrence of *hemoconcentration* shown by increased oxygen capacity of blood (Table 1). In some tests it amounted to as much as 30 per cent. The cause of hemoconcentration was thought to be due to a loss of fluid through capillaries damaged by asphyxia and possibly an increased mobilization of red blood cells from the spleen. Essentially a condition of shock supervenes. The blood, moreover, was difficult to withdraw because of the tendency to clot. In histologic sections of the lungs, cell packing in blood vessels was prominent. Agglutination was not observed.

It must be borne in mind that complete recovery follows the proper treatment of compressed air illness provided that paralysis does not develop. This fact is *a priori* evidence that agglutination and appreciable parenchymal damage from intra- or inter-cellular cavitation do not take place. In rapid decompression simulating ascent to high altitudes, bubbles have been demonstrated in cerebrospinal fluid and in joint spaces. It is not considered likely that such extravascular accumulation of gas plays an etiologic role under the conditions in which men, in contrast with lower animals, are decompressed from high pressure atmospheres.

TABLE 1

ANALYSIS OF OXYGEN CONTENT OF BLOOD FROM ANESTHETIZED DOGS RAPIDLY DECOMPRESSED FROM HIGH PRESSURE ATMOSPHERES*

Exposure	Period	Volume Per Cent Oxygen Content		Arterial Venous Difference	Oxygen Capacity	Per Cent O_2 Saturation		Pressure CO_2 Arterial Blood
		Arterial	Venous			Arterial	Venous	
9†	Control	15.9	10.1	5.8	17.7	90	57	45
	Following decompression	5.4	0.5	4.9	22.4	24	2	59
	Recompression	17.9	7.9	10.0	20.3	88	39	
	Following recompression	5.9	2.3	3.6	22.8	26	10	
10‡	Control	20.6	17.0	3.6	22.8	90	75	
	Following decompression	14.6	7.7	6.9	26.1	56	30	
	Recompression	31.7§	20.0	11.7	27.3	100	64	
	Following recompression	26.9	7.3	19.6	29.8	90	24	

* Data from Behnke *et al.*, Am. J. Phys., *114*: 526, 1936.
† Air inhaled during two-hour recompression period.
‡ Oxygen inhaled during two-hour recompression period.
§ 4.4 volumes per cent oxygen in physical solution.

Apart from asphyxia and its complications, *paralysis* usually in the form of spastic paraplegia of the hind extremities was observed in dogs. Foot drop, paresis of hind limbs, and genito-urinary disturbances were occasionally manifest. That the spinal cord rather than the brain is primarily involved, is evident from the older studies.

IN MAN.—From these controlled experimental data one gains a better understanding of the symptomatology in man. *Asphyxia* or "chokes" is usually manifest by shallow, rapid

respiration, dyspnea, and cyanosis, or by a pale, ashen gray appearance. Visual disturbances of an asphyxial nature are not infrequent.

We have noted that an early sign indicative of bubbles in the pulmonary vascular bed is a sensation of *substernal distress*, especially during deep inspiration, which elicits the cough reflex. In this condition habitual smokers are unable to tolerate the inhalation of tobacco.

The incidence of *paralysis*, while at present rare compared with the old reports, is the most serious complication of compressed air illness. The manifestations in man are similar to those observed in dogs, and indicate ischemic involvement and necrosis particularly of the thoracolumbar segments.

Residual injury pointing to involvement of the spinal cord is seen among the older sponge fishermen of Florida who have not had access to proper recompression treatment.

Demonstrable *injury of the cerebrum* in contrast with the spinal cord, and apart from asphyxial damage, is rare. Ménière's syndrome was described not infrequently in the older reports and is thought to be due to embolic deprivation of blood supply to the inner ear. It is certain that pressure trauma does not cause the entity.*

The most common manifestation of compressed air illness is a *dull, aching type of pain*, shifting in character, and frequently felt in the joints, or deeply in muscles and bones. Pain or pains of this nature are referred to as *bends*, a term established by usage to denote a well recognized clinical entity.

A most likely location giving rise to bends is bone, particularly the marrow with its high absorption coefficient for nitrogen. Furthermore, the sluggish, sinusoidal type of circulation in the marrow and the natural obstructions to the exit of bubbles possible only through the dichotomous branches of a vein traversing the rigid-walled cortex serve to make the bones a trap for gas bubbles disseminated from the general circulation or forming in situ in the marrow spaces. From

* It should be pointed out here that there is an urgent need for a study of the histologic changes produced in the central nervous system as a result of rapid decompression.

the point of view of body economy the bones constitute the weak organ that renders man unsuited for long exposures in compressed air.

That bubbles are present in the marrow is inferred from the intensified pain experienced by some patients during early recompression. This type of pain is believed to arise from a difference in pressure or an actual squeeze of bone marrow tissue during the too rapid compression of bubbles to allow the body fluids to replace the suddenly diminished gas volume within the bone cortex.

Recent reports of characteristic lesions in bone appearing in caisson workers support the view that the symptoms giving rise to bends originate in part certainly from *ischemic changes in bone*. Kahlstrom, Burton, and Phemister,[12] Coley and Moore,[13] and Rendlich and Harrington[14] describe lesions in diaphyses and epiphyses of long bones complicated by joint involvement and attributed to aseptic necrosis of bone or interference with nutrition occurring secondary to the interruption of blood supply by liberated nitrogen gas.

However, the etiologic relationship between the presence of these lesions and embolic injury must be corroborated by additional findings and animal experiments before final conclusions can be drawn. In divers suffering repeatedly from experimental bends, Lieut. Walter Welham, (M.C.), U. S. Navy, and the writer found no characteristic lesions in a roentgenologic study at different periods following injury.

Some factor such as multiple, repeated injury, concomitant infection, or anomalous blood supply must operate in conjunction with embolism to produce the described changes. The analogy that may be drawn to the relationship between the ingestion of alcohol and cirrhosis of the liver suggests that an integrative analysis is required to evaluate the findings.

That interference of gas emboli with the blood supply to muscles may also form part of the picture of bends appears probable from the effects of too rapid decompression in a helium atmosphere. The decreased solubility of helium in fat renders the incidence of bone lesions less likely than the incidence of these lesions following air decompression.

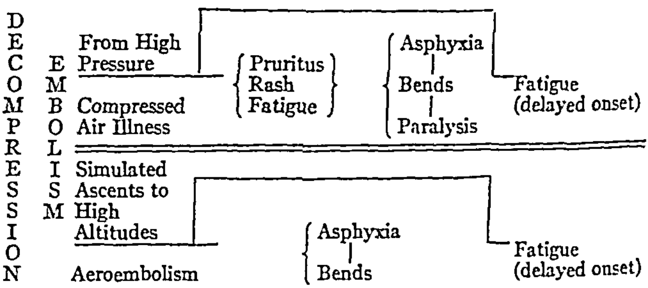
Fatigue is a symptom of especial interest which may be

prodromal or subsequent to bends. In experimental borderline decompressions, fatigue is frequently the first sign of excessive bubble formation. In association with bends, fatigue may take the form of an exhausting malaise combined with chills, fever, and sweating.

Minor symptoms as *skin rash* and *pruritus* occur with regularity if the skin is chilled during decompression.

It is important to bear in mind that the *onset of symptoms* may be delayed as long as twelve hours following decompression and that sudden collapse may occur without warning in an apparently well individual three or four hours following decompression. The failure to consider these probabilities has led to inexcusable errors.

The following diagram may clarify the symptomatology of decompression embolism:



Our deep-sea divers have experienced symptoms during simulated ascents to high altitudes identical with the bends characteristic of compressed air illness.

Diagnostic Considerations

Since intravascular bubbles have access to every part of the body, one must be aware of the protean nature of compressed air illness. The diagnostic rule is to regard every unexplained symptom following work in compressed air as caused by bubble formation. Serious errors have been made by not applying recompression at least as a diagnostic procedure.

On the other hand, patients have developed appendicitis during decompression, and a fracture of the neck of the

femur was said to have been overlooked in a patient treated for compressed air illness.

Principles Underlying the Prevention of Compressed Air Illness

The prevention of compressed air illness depends upon the *elimination of nitrogen* absorbed during exposure to increased barometric pressure without excessive bubble formation in the blood stream.

From Fig. 175 it is observed that about 75 per cent of the total body nitrogen is eliminated at a comparatively rapid rate and hence does not usually contribute to the formation of bends. There appears to be, however, a relatively small amount of gas in the fatty bone marrow that requires many hours for proper elimination.

At a depth of 90 feet, for example, 10.5 hours of air decompression were required following a nine-hour exposure (probable saturation). On the other hand, a two-hour exposure (75 per cent saturation) at the same depth required only fifty-nine minutes for decompression (Table 2). Nine and one-half hours were therefore required for the dissipation of the remaining excess gas amounting to but 25 per cent of the total present in body tissues.

From our point of view the body may be compared with a mixture of water and fatty material contained in a beaker. Of the fat an important fraction is surrounded by bone representing marrow and spinal cord substance. This bone-contained fat may be considered as lying in the bottom of the beaker.

If the contents of the beaker are now exposed to a high nitrogen pressure for a short period of time and then quickly returned to atmospheric pressure, diffusion of nitrogen will take place from the water into the surrounding air and also into the unsaturated water and fat. Following short exposures the partially saturated fat appears to act as a buffer against bubble evolution. By contrast, after long exposures the large reservoir of nitrogen in the saturated fat constitutes the predisposing cause to embolism. The nitrogen within the bone, moreover, will require many hours for removal.

With reference to the matter of *tolerance for abrupt re-*

ductions in pressure, the body may be exposed to a compression of 4 atmospheres for a period of twenty-seven minutes followed by a rapid decompression to the normal level in two minutes. A period of ninety minutes, however, at the same pressure and followed by the same period of decompression would prove fatal.

The nitrogen absorbed in the early part of decompression and presumably dissolved in the body fluids is therefore

TABLE 2

CHAMBER DECOMPRESSION FOLLOWING PROLONGED EXPOSURE IN COMPRESSED AIR

Simulated Depth (Feet)	Exposure Time (Hours)	Decompression Time (Minutes)	Remarks
30	12	1	No symptoms
38	5	1.5	No symptoms
38	7	1.5	No symptoms
38	9	1.5	Bends 3 hrs. following decompression
38	9	1.5	No symptoms. *Oxygen* 6 hrs. at surface
38	12	1.5	Bends 2.5 hrs. following decompression
38	12	1.5	No symptoms. *Oxygen* 6 hrs. at surface
60	6	69 (Air)	No symptoms
60	12	237 (Air)	Bends 10.5 hrs. following decompression
60	12	311 (Air)	No symptoms
Diver C. 60	12	79 (O_2)	Oxygen 2.2 hrs. at surface. No symptoms
Diver C. 60	12	79 (O_2)	Oxygen 4.3 hrs. at surface, bends 5 hrs. following decompression
Diver S. 90	2	59 (Air)	No symptoms
90	6	310 (Air)	No symptoms
90	9	458 (Air)	Bends 2 hrs. following decompression
Diver S. 90	9	583 (Air)	Bends 1 hr. following decompression
90	9	638 (Air)	No symptoms

readily eliminated by any method of decompression. In the rapid drop from 4 to 1 atmosphere, a degree of supersaturation appears to be tolerated by the body approaching a ratio of 4 to 1. By contrast, when the body is saturated at a pressure of 4 atmospheres, requiring a saturation period of nine to twelve hours, a ratio indicative of supersaturation of only 1.2 to 1 will not hold throughout the whole period of decompression.

Furthermore, during rapid decompression in the low pressure chamber, apparently ratios between the pressure of gas in the body and the ambient pressure of 3 to 1 or even 4 to 1 exist, *i.e.*, 1 atmosphere to 0.33 atmosphere or to 0.25 atmosphere.

On the basis of these facts the degree to which the body appears to hold gas in a state of supersaturation is *relative* and depends not only upon the degree of saturation but also upon the pressure level.

TABLE 3

PRESSURE SHIFTS AND INTERVALS OF WORK FOR EACH TWENTY-FOUR-HOUR PERIOD (New York State Tables)

Pressure		Hours			
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Minimum Number of Pounds	Maximum Number of Pounds	Maximum Total	Maximum First Shift in Compressed Air	Minimum Rest Interval in Open Air	Maximum Second Shift in Compressed Air
Normal	18	8	4	½	4
18	26	6	3	1	3
26	33	4	2	2	2
33	38	3	1½	3	1½
38	43	2	1	4	1
43	48	1½	¾	5	¾
48	50	1	½	6	½

Application of Physiologic Principles.—The important consideration is not mastery of a method of computing the decompression table on the basis of a ratio but rather the acquisition of an understanding of the *basic* physiologic principles of which one of the most important is the realization of the difficulty in getting excess nitrogen out of fatty tissue, especially the bone marrow.

From the point of view of field practice this difficulty has been overcome by progressively limiting *the time of exposure* in compressed air as the working pressure is increased. The New York State tables (Table 3) represent the culmination of this type of experience.

If it is desirable to increase working time at higher pressures three methods resting on a sound physiologic basis are available: (1) keep workers in a compressed air atmosphere for prolonged periods of time followed by slow decompression, (2) employ helium-oxygen mixtures in place of air, (3) employ oxygen during decompression.

1. *Prolonged exposures* in compressed air for periods of at least seven days at pressures of 30 pounds gauge have been made repeatedly. From the point of view of physiologic response and work output, the attempt to decompress men twice daily is not only potentially dangerous but highly uneconomical.

At a pressure of 50 pounds gauge, for example, the working time is under present conditions necessarily limited to about forty-five minutes. This time could be extended for a period of hours depending upon the capacity of individuals for work, were not the danger of bubble formation imminent following even long periods of decompression.

It would appear advisable therefore to keep men at work on a job continually under pressure. Following a work shift at maximum pressure, the pressure could be lowered rapidly to between 20 and 30 pounds and maintained at this level during the rest and sleep period. The final decompression prior to emergence into a normal atmosphere would be uniform over a period of eight to twenty-four hours.

2. *Value of Helium-Oxygen Mixtures.*—Since the objection to long exposures lies in the difficulty of eliminating the gas dissolved in fatty substance, the employment of helium with its low solubility coefficient in fat would appear to be ideal.

In diving tests, following short exposures in the compressed helium-oxygen or air atmosphere, the body fluids are well saturated with either gas and no particular advantage in decompression accrues from the use of helium (Table 4). Following long exposures, decompression time may be reduced as much as 75 per cent. Part of the reduction in decompression time is brought about by the inhalation of oxygen at the lower decompression stops, but the important factor is the lessened uptake of helium by fat.

In altitude test runs oxygen inhalation for a period of five

hours is required under certain conditions to prevent aeroembolism. If the body nitrogen be removed and helium substituted, the time for oxygen inhalation can be reduced to at least ninety minutes or a reduction of 70 per cent.

Whether or not the employment of helium is practical in caisson work depends upon the development of a method of economical administration.

In deep-sea diving exposures are usually short and the advantage derived from helium is that it renders unimportant the narcotic effect of nitrogen as demonstrated in the *U.S.S. Squalus* salvage operations.

TABLE 4

COMPARISON OF TOTAL DECOMPRESSION TIME FOLLOWING EXPOSURE IN COMPRESSED AIR AND EXPOSURE IN A HELIUM-OXYGEN ATMOSPHERE

Depth (Feet)	Exposure (Minutes)	Decompression (Minutes)	
		Air	Helium-Oxygen
90	100	50	75
90	180	...	77
90	360	...	79
90	540	638	79
150	80	141	121
150	180	...	126
150	360	...	128
200	65	217	154
200	90	...	164

3. *Value of Oxygen.*—Essentially oxygen inhalation permits the elimination of an inert gas at a maximum pressure head as shown by the graph (Fig. 175), and at a pressure level sufficiently high to prevent injury from massive bubble evolution.

During the past three years the Navy has used oxygen routinely in helium-oxygen diving during the latter part of the decompression period beginning at the 60-foot level.

In air diving the British have had a great deal of experience with oxygen inhalation and the reader is referred to the book, "Deep Diving and Submarine Operations," by Robert H. Davis.[15] A reduction in decompression time of about 40 per

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of carbon dioxide in the compressed atmosphere, have been discussed in previous paragraphs.

Danger of Too Rapid Ascent to the First Stop.—The tendency in diving is to bring men too rapidly to the first stop which usually is at one half the depth compared with the original level. This procedure leads to the initiation of the bubble state in the early part of decompression when the pressure head of gas in the tissues is highest.

Symptoms indicative of embolism have appeared during helium-oxygen diving at depths of 180 and 90 feet on two occasions following too rapid ascent from depths in excess of 300 feet. At present for helium-oxygen diving the rate of ascent is limited to 25 feet per minute and an arbitrary period of seven minutes is taken at the first stop in order to permit the blood to transport to the lungs the large amounts of helium diffusing into the blood stream.

It has been possible to show by actual measurements that too rapid decompression in the early stages leads to an accumulation of gas probably in bubble form so that equal quantities of gas are eliminated during each of the first two thirty-minute periods; if the blood stream is not overloaded, about two and one-half times more gas is given off during the first thirty-minute period compared with that eliminated during the second period (Fig. 175).

In air diving the reduction in rate of ascent to the first stop from 50 to 25 feet per minute greatly reduced the incidence of embolism manifested by the occurrence of pruritus and rash.

Selection of Personnel.—A routine physical examination may not be adequate to determine those individuals who are qualified for work in compressed air. We therefore employ specific *pressure tests* for the selection of fitted men.

With reference to patency of auditory tubes and presumably freedom from infection of the upper portion of the respiratory tract, the immediate application of a pressure of five pounds in the chamber will serve to select the qualified men. The assumption is made that the men have previously been instructed in the matter of "clearing their ears." Inspection of the tympanic membrane following the application of

cent is effected by the employment of oxygen according to British experience.

Following prolonged exposures in compressed air at comparatively shallow pressure-depths we have had the opportunity to test the value of oxygen and some of the data are recorded in Table 2. Under the conditions of these tests the long exposures in hot compressed atmospheres brought on fatigue which seemed to render variable the susceptibility of men to bends.

In one test the inhalation of oxygen for a period of seventy-nine minutes in the compressed atmosphere was adequate for decompression. In another similar test the same individual developed bends. Finally the oxygen decompression period had to be increased to one hundred and sixty-one minutes for the saturation exposure of twelve hours at a simulated depth of 60 feet. However, the corresponding decompression period in air was three hundred and eleven minutes.

The data in Table 2 demonstrate the value of oxygen inhalation following decompression at the surface level. Thus, the depth could be increased from 33 to 38 feet provided that oxygen was inhaled following abrupt decompression to the surface.

The conclusions drawn from these tests is that a considerable reduction in decompression time is brought about by oxygen. On the other hand, the occurrence of bends following a period of oxygen inhalation of ninety minutes during the initial stage of decompression demonstrates again the difficulty in getting rid of the comparatively small residual fraction of nitrogen in slowly desaturating tissue (bone marrow).

Oxygen inhalation undoubtedly serves its best purpose in preventing the serious symptoms of compressed air illness and its chief value lies in clearing the blood stream and body fluids of the excess nitrogen.

Further Principles Underlying the Prevention of Compressed Air Illness.—The value of exercise in promoting a more rapid elimination of nitrogen during the early part of decompression, and the danger inherent in the accumulation

4. Careful selection and the maintenance of personnel in good physical condition.

Treatment of Compressed Air Illness

The prime requirement in treatment is the *rapid restoration of normal blood supply by compression and absorption of the obstructing gas emboli*. Behnke and Shaw[9] formulated a procedure of recompression utilizing oxygen, based on laboratory experiments (see Table 1) and later Yarbrough and Behnke[16] applied the principles to field practice.

In repeated treatments administered by this method incident to experimental diving and in submarine salvage operations, no significant change in procedure from that outlined in the original papers has been made. It has proved to be satisfactory.

Recompression.—Essentially the basis of treatment is prompt recompression and the inhalation of oxygen. Figure 176 serves as a guide in the recompression procedure. It is emphasized that the condition of the patient governs the detailed mode of therapy rather than rigid adherence to a system of tables.

Perhaps there is no therapeutic procedure more effective than recompression as applied to the asphyxiated, pulseless, cyanotic patient whose blood stream is filled with multiple gas emboli. Even patients presenting incipient lesions of the spinal cord have made complete recovery under immediate and prolonged recompression.

In the mild cases of compressed air illness characterized by bends, the minimum pressure applied in recompression is 45 pounds per square inch (gauge) equivalent to a diving depth of 100 feet. Relief of symptoms may occur at greatly reduced pressures but the additional compression reduces the size of the bubble 75 per cent compared with surface volume, and ensures against the initiation of lesions in the spinal cord.

For the serious cases characterized by asphyxia, probable involvement of the nervous system, or both conditions, recompression is limited to a pressure of 75 pounds gauge equivalent to a depth of 165 feet. At this pressure the surface size of the bubble has been reduced 83 per cent; higher pres-

pressure reveals the degree of ability to accommodate to excess pressure. Two tests with an interval of several days intervening should be accorded an applicant who is otherwise in good physical condition.

With reference to susceptibility to bends, it follows from a consideration of the physiologic data that the elimination of excess nitrogen without the development of manifest air embolism depends upon effective blood flow through tissues and the absence of excess fat. The desirable type of man is therefore young and lean. Yet among such individuals the variation in susceptibility to compressed air illness makes necessary a specific *decompression test for the selection of deep-sea divers.*

This test consists in reducing the pressure from 1 atmosphere to 0.25 atmosphere during a period of seven minutes. Oxygen is inhaled at the start of pressure reduction. The duration of stay in the rarefied atmosphere is for a period of one hour. Under these conditions susceptible men develop bends while those men who are comparatively immune remain free from symptoms.

Too much stress cannot be laid on the necessity for the *maintenance of good physical condition* by men who work in compressed air. Empirical data indicate that any condition tending to impair cardiovascular tone renders men susceptible to the development of decompression embolism. Indulgence in alcohol should be specifically interdicted. Fatigue, infection, hot atmospheres, and excess carbon dioxide in the air are all factors associated with increased incidence of bends. Our deep-sea divers, therefore, maintain a system of training similar to that followed by the athlete.

Summary of Principles.—The following principles underlie the prevention of compressed air illness:

1. Limitation of time of exposure in compressed air or the employment of helium-oxygen mixtures for saturation exposures.
2. Reduced rate of ascent in the early stages of decompression.
3. Slow decompression following long exposures and the inhalation of oxygen at the lower decompression levels.

4. Careful selection and the maintenance of personnel in good physical condition.

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sures can do little to improve circulation and would unduly delay the pressure at which oxygen could be breathed.

The next stage is the *maintenance of the maximum pressure* for a period of thirty minutes. Usually this period of

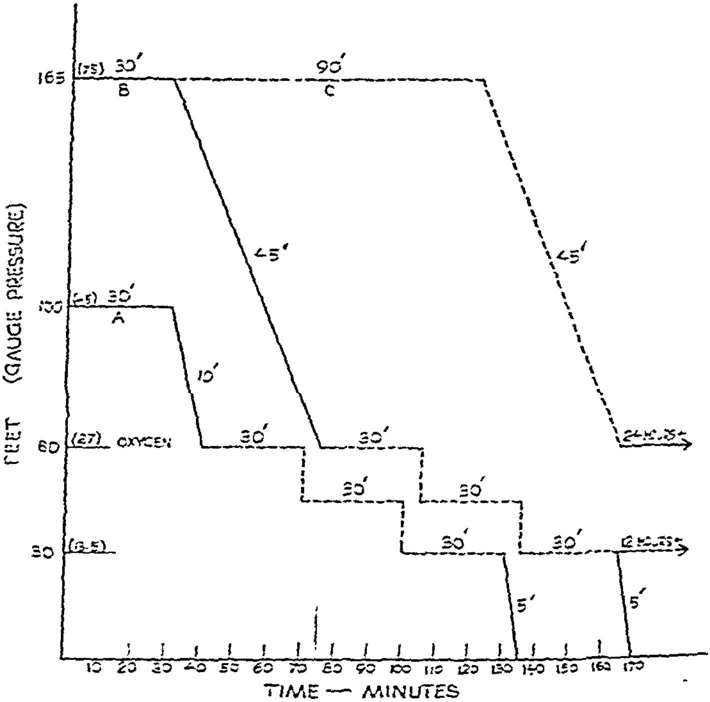

Fig. 176.–Guide for treatment of compressed air illness (after Behnke and Shaw, Yarbrough and Behnke).

A–For "bends."

B–For "bends"–asphyxia.

C–For asphyxia/paralysis.

At maximum pressure patient inhales air, or helium-oxygen of about (70:30 ratio) mixture.

At 60-foot level or below, patient inhales oxygen *for ninety-minute* period. Attendant inhales oxygen for thirty-minute period.

For prolonged recompression at or below 60 feet, air is inhaled.

time is sufficient to ensure apparently complete recovery but should paralysis be present or suspected, or if the patient remains unconscious, the maximum pressure is maintained for an additional ninety minutes (Fig. 176, C).

At the maximum pressure, *air*, or if available, a mixture of *helium-oxygen* (about 70:30 ratio) is inhaled. At the end of the thirty-minute period the pressure is decreased uniformly for forty-five minutes until the 60-foot level (27 pounds gauge) is reached (Fig. 176, B). If a pressure of 45 pounds has been used (Fig. 176, A), a period of ten minutes is sufficient for decompression to the 60-foot level.

Oxygen inhalation is begun at the 60-foot level and continued for a period of ninety minutes until the 30-foot level is attained. If the patient exhibits an idiosyncrasy for oxygen, the usual symptom being *nausea*, oxygen inhalation is postponed until the 45- or 30-foot levels are attained. Air or the helium-oxygen mixture is inhaled for the period of time at the 60- or 50-foot levels that would otherwise have been devoted to the inhalation of oxygen.

It is unlikely that intolerance for oxygen will exist at the 45- or 30-foot levels and a period of ninety minutes for oxygen inhalation should be feasible for all patients prior to the termination of decompression.

Decompression* is then terminated from the 30-foot level by a uniform drop to the normal atmosphere over a period of five minutes.

For mild cases of compressed air illness this type of treatment usually affords permanent relief. Should symptoms recur in more seriously injured patients, recompression is again effected to a level between 30 and 60 feet for a period of twelve to twenty-four hours followed by a gradual return from the 30-foot level to the normal atmosphere during a period of four hours.

This practice of prolonged immersion in compressed air colloquially termed "the overnight soak" has proved to be the conclusive method of terminating treatment. The patient is permitted to sleep and the bubbles have adequate time for absorption. Should there be any question of involvement of the central nervous system, the prolonged immersion treatment is routinely put into effect.

For the moribund patient, the pressure level following the

* For the *attendant* a thirty-minute period of oxygen inhalation should ensure adequate decompression.

two-hour treatment at a depth equivalent to 165 feet, is decreased to 60 feet during a period of forty-five minutes. Oxygen is then administered for ninety minutes, and *air inhalation is continued for a period of twenty-four hours or longer.* There should be no hesitancy in continuing treatment at the 60-foot level for a period of days. The increased partial pressure of oxygen at this level is also an effective therapeutic measure in treating the incipient or manifest pulmonary edema, anticipated as a complication of extensive embolism of the pulmonary bed (see Fig. 176, C).

Adjuncts in treatment are the judicious injection of glucose and saline solutions, or plasma in the severely injured patients in order to counteract the effect of hemoconcentration. The use of adrenalin and the application of warmth are additional measures if the shock syndrome is present.

The position of the patient's body should be recumbent since the site of bubble accumulation is influenced by gravity.

Errors in treatment have been:

1. Failure to apply the pressure test in doubtful cases, "It can't be compressed air illness."
2. Delayed recompression. The potential patient avoids the doctor.
3. Failure to keep the moribund patient at the 60-foot level.
4. Failure to keep the "treated" patient near the recompression chamber for a twenty-four-hour period.

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THE PNEUMOCONIOSES

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The pneumoconioses include all chronic changes in the lungs induced by prolonged inhalation of dust with no implication as to type or severity of tissue reaction. The latter may vary from simple phagocytosis to progressive fibrosis. Excluded from this category are the responses to living bacteria and fungi which are occasionally inhaled as dust.

A variety of specific terms has been introduced to indicate the kind of dust responsible for the pulmonary condition. The use of such terms is only desirable when the character of the reaction is distinctive and leads to significant clinical symptoms. In the group of pneumoconioses belong *silicosis*, the condition produced by inhaling quartz or other forms of free silica, *asbestosis*, the condition resulting from inhaling various fibrous silicates, and a few others not yet specially designated.

Since most other forms of dust in pure state have essentially the same effects upon the lungs and since none of them appreciably influences respiratory function the writer has proposed that reaction to them be designated by the common term, *simple benign pneumoconiosis*. Included under this term are uncomplicated *anthracosis* from coal, and *siderosis* from iron. When these minerals are mixed with quartz a modified type silicosis may develop which is properly designated as *anthraco-silicosis* and *sidero-silicosis*.

Dusts of vegetable origin, like tobacco, grain, cotton fiber, and so on may be inhaled but probably they cause little anatomical change. They may, however, sensitize tissue and give rise to allergic symptoms. Although these conditions produce insignificant structural alteration in the lungs, their

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special designations, like *tobaccosis and thresher's fever*, are not infrequently listed as forms of pneumoconiosis.

This group of conditions almost invariably develops in industry because only in its environment are the necessary concentrations of fine dust particles constantly maintained. In the state of nature there is dust, but the concentrations are rarely excessive, the particles are relatively coarse, and exposures are intermittent. The human race has evolved in such an environment and its lungs are protected against ordinary amounts of dust. The tortuous upper respiratory passages exclude most of the contaminants of inspired air, the ciliated epithelium lining the nose, trachea, and bronchi carries back to the pharynx many of the particles that lodge on its surface. It is estimated that at least 50 per cent of the dust in the air we breathe fails to reach the depths of the lungs. The free phagocytes wandering over the surface of the air spaces ingest and carry off particles that pass these barriers. The lymphatics of the lung remove phagocytosed and probably free particulate matter and deposit it in lymphoid tissue where it is no longer in contact with respiratory membranes. These mechanisms are adequate to protect man against all but extraordinary concentrations of dust.

Evidence of such protection may be seen at almost any autopsy where the heavily pigmented tracheobronchial lymph nodes attest the amount of carbon and other minerals removed from the lungs. Not infrequently the nodes of persons who have been exposed in industry to moderate concentrations of fine quartz reveal clusters of microscopic silicotic nodules while the lungs themselves remain free of such reaction.

ETIOLOGY

To have significant effects, the atmospheric concentrations must be excessive, the exposure to dust must be prolonged over periods measured in years, and the particles must fall within a particular size range. Within limits these factors bear a reciprocal relationship to one another, but under no circumstances is it possible to reduce the time factor much below *two years* even in the case of the most potent dusts. It takes time for effective quantities of dust to accumulate

within the lungs and more time for the particles to react upon the tissues.

The Size of Particles.—The size of the particles must be small enough to permit them to remain suspended in the air and to pass the barriers of the upper respiratory tract. The latter prerequisite is influenced by their shape and flexibility. Of the particles that are roughly spherical, few larger than 10 microns in diameter are found within the air spaces, but fibers of asbestos as long as 60 microns are relatively common and some have been seen that measured 200 microns. On the other hand, even short fibers of fine glass wool seem to be practically uninhalable because they are stiff and inflexible.

Where a mineral is chemically irritating, the factor of size has further importance because the smaller it is the greater the surface area exposed to contact with the tissue. Experiment has demonstrated that there is little reaction to particles of quartz between 3 and 10 microns in diameter, but that below the critical size of 3 microns the intensity of tissue response increases as the size of the particles decreases. There is probably a lower limit of effective size which is determined by the amount of retention within the air spaces. Particles smaller than this unestablished limit are exhaled with the air or eliminated through the blood and urine and hence do not accumulate to produce effective concentrations.

PHAGOCYTOSIS AND DISTRIBUTION WITHIN THE LUNG

Regardless of the character of the minerals in a dust the particles inhaled into the terminal air spaces are ingested by free phagocytic cells that develop in the adjacent walls. The subsequent disposition of the foreign bodies is more or less influenced by their *nature* and *quantity*. Small amounts of inert particulate matter like soot, coal, and iron are transported by the phagocytic cells through the lymphatic vessels to lymph nodules within the lungs. Here they may remain but there is a tendency for most of them to be carried on to the nodes about the bifurcation of the trachea. After the latter have accumulated excessive amounts of dust, more particles begin to collect in the lymph nodules within the

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lungs themselves. This order of disposition suggests stasis from obstructive reaction in the nodes at the root of the lung. It is practically never complete, however, for even sclerosed silicotic lymph nodes become involved in a superimposed lobar pneumonia or pulmonary cancer.

When larger amounts of dust of the same type are inhaled all of the phagocytes do not remain within the lymphatic vessel; many accumulate within the surrounding connective tissue. This is evidenced by the delicate perilymphatic pigmentation which outlines the lobules presenting on the pleural surface and by similar deposits in the walls of blood vessels traversing the depths of the lungs. On exposure to excessive atmospheric concentrations of dust the protective mechanisms are entirely inadequate and dust-filled phagocytes remain in the alveoli for years.

The *solubility* of particulate matter also influences its disposition. Readily dissolved particles like those of marble and gypsum quickly disappear either before or after they have been ingested by phagocytic cells and leave practically no evidence of their presence. Toxic substances like fine quartz, on the other hand, exert their first effects upon the phagocytes. The cells undergo a series of changes comparable to those excited by the tubercle bacillus, including epithelioid alterations and giant cell formation. Necrosis occurs but it rarely involves the large numbers of cells seen in tuberculosis so that the gross appearance of caseation is lacking. However, numerous isolated phagocytes are killed, liberating the quartz that they have already ingested and thus creating a demand for more cells of the same kind. As a consequence the picture of early silicosis is a much more active one than that of the corresponding stages of any other form of pneumoconiosis. Phagocytes not killed but injured tend to adhere to one another and hence there is a pronounced tendency to form tubercle-like nodules.

Fibrous material. like asbestos, is not handled so effectively. The same type of phagocytes attempt to ingest inhaled asbestos but the fibers are so long that they project beyond the margins of the cell. This appears to impede ameboid activity and as a consequence there is little or no transport to

the lymphatic system. Asbestosis, accordingly, begins about the terminal respiratory bronchioles, where most of the inhaled fibers come to rest.

SIMPLE BENIGN PNEUMOCONIOSIS

Gross Anatomy

In the absence of associated infection the pleural surface is smooth and free from adhesions. There is usually *pigmentation* distributed in small focal areas, in linear deposits along the pleural lymphatics or diffusely, the amount varying with the intensity of the exposure. The sectioned lung again reveals varying amounts of pigmentation. In the slighter degrees one sees scattered flecks of black pigment, not over 2 or 3 mm. in diameter, in the centers of the lobules or fine linear deposits along the lymphatics in the walls of smaller arteries and in the septa between lobules. The old soft coal miner's lung may be uniformly black in color with here and there a small collection of emphysematous air spaces. Regardless of size or intensity, none of these pigmented areas is fibrous and palpation fails to differentiate them from the surrounding lung. Inspection with a lens reveals normal structure underlying the pigmentation.

The microscope demonstrates that the pigment is largely contained within phagocyte cells which may be located within the air spaces or in the areolar framework of the lung. In the latter situation these *dust cells* are often elongated and simulate connective tissue cells but as Haythorne has demonstrated, the development of edema separates the supporting cells and permits the phagocytes to assume their primitive rounded or oval forms. In marked cases heavy collars of pigmented cells will be found about the smaller arterioles. In cross section these deposits simulate ill-defined nodules but closer scrutiny reveals the central blood vessel. When cut longitudinally their true nature is more obvious. While such tissue changes are not infrequently associated with appreciable amounts of newly formed connective tissue, chemical analysis generally demonstrates unusual quantities of free silica. In such cases it is the invisible silica which has been responsible for most of the tissue reaction. More rarely no excess of silica is demonstrable and in these instances it seems probable that a healed infectious process may have produced a fibrosis in which the inhaled pigment has accumulated. This interpretation seems logical in view of the paucity of such cases and the repeated demonstration in animals of the lack of fibrosis on exposure to pure minerals of this class.

Roentgenologic Findings

A roentgenogram of the chest of a subject with simple benign pneumoconiosis reveals that the linear shadows normally cast by the blood vessels are thicker than usual and extend further into the periphery of the lung. No new shadows are observed. This picture is confusing to observers not thoroughly familiar with possible variants of the "normal" pattern. It is probably safe procedure to regard nothing

but very well defined linear exaggeration as evidence of reaction to inhaled dust. In no case should it be so regarded where the change is not uniform throughout all parts of both lungs. A further source of confusion arises from the fact that exposure to free silica dust, insufficient to produce definite and characteristic nodular roentgenographic patterns, may also cause exaggeration of the linear markings. Since it is impossible to distinguish between "early" silicotic reactions and those of nonspecific origin, it is unsafe to classify such films as presilicotic. In surveys or in annual reexaminations of large groups of men whose industrial exposure is thoroughly understood, such a diagnosis is a reasonable probability, but in an isolated case, seen on a hospital ward, the chances of error are great.

Clinical Picture

Simple benign pneumoconiosis ordinarily causes no symptoms. Disability is hard to imagine in view of the distribution of the dust reaction in the framework of the lung. *Physical signs* are usually absent although in some instances those indicative of chronic bronchitis may be elicited. The diagnosis depends upon a *history of adequate exposure* to dust supported by evidence of definite alterations in the roentgenographic pattern. But it should always be borne in mind that the latter is not pathognomonic, that inhaled dust is only one of the possible causes. Healed infections may also produce slight degrees of linear exaggeration, but in this case the distribution is apt to be less uniform.

Complications

Susceptibility to infection is not appreciably modified by simple benign pneumoconiosis although the nature of the causative dust influences the frequency of this complication. Acute pulmonary infections are no more common than in the population at large; the incidence of chronic infections like tuberculosis may be slightly elevated in the case of persons breathing dusts containing an adequate mixture of free silica. Where dusts of calcium compounds are concerned the frequency of tuberculosis is generally very low.

SILICOSIS

Gross Anatomy

The characteristic lesion of silicosis is a *localized nodule* of dense, hyaline, fibrous tissue not over 3 or 4 mm. in diameter. Inspection of typical silicotic lungs reveals nodules of this nature seeded over the pleural surface and uniformly scattered throughout all parts of the depths of both organs. Where the condition is of long standing there may be a zone of emphysema, free of nodules, over the diaphragmatic surfaces and where there are scars of old infections the uniformity of the distribution is invariably disturbed.

In the absence of infection the pleural surface is free from adhesions and, except for the elevated nodules, is smooth. *Pigmentation* is variable but in most cases there is enough associated carbon or other colored minerals with the silica to produce a diffuse or localized black color. In such cases the slightly raised centers of the colorless silicotic nodules stand out in sharp contrast. As silica tends to accumulate more rapidly in this location, the pleural manifestations may be the only definite evidence of early silicosis. However, palpation of the foci of pigmentation in the deeper parts of the lung usually reveals some that are firm enough to be differentiated from the surrounding tissue. Inspection of such foci with a lens demonstrates local obliteration of the normal structure. In well marked cases the uniform distribution of the firm discrete nodules constitute unmistakable evidence of silicosis.

Where the proportion of associated minerals is relatively large, the form of the silicotic nodule is often modified. About each is an ill-defined zone of heavy pigmentation which may communicate with similar deposits along arterioles or other structures containing lymphatic trunks. Sometimes the pigmentation is so intense that the firm, hyaline nodules are almost obscured. These modifications produce general patterns more suggestive of a linear network than the typical nodulation. They are most common in anthraco- and sidero-silicosis.

The tracheobronchial lymph nodes are practically always deeply pigmented from associated colored minerals. In the early phases of silicosis the nodes are enlarged but later, as the fibrosis matures, they contract to a size only slightly larger than normal and become as hard as the sole of a shoe.

The *reaction* to silica particles is progressive to the extent that nodules of microscopic dimensions increase until they attain a diameter of 2 to 4 mm. regardless of further exposure. However, on attaining their maximum size the lesions remain stationary and new ones do not develop. From then on only the development of associated infection is likely to involve new portions of the lung.

Many cases of silicosis fail to conform to this classical pattern. The pleural surface is obscured by *dense fibrous adhesions* and on sectioning the lung large, black masses of rubbery consistence have replaced variable amounts of air-containing tissue. Discrete nodules usually occur elsewhere but sometimes they are detectible only along the borders of the massive fibrosis. Coarse emphysema, not infrequently of bullous type, is a usual complication. The large *conglomerate lesions* most often occur in the upper thirds of one or both lungs. Sometimes bilaterally symmetrical masses radiate from the hilum into each lung involving perhaps portions of two

or more lobes with obliteration of the fissures. At other times a solid prism of such scar is discovered parallel to but 3 or 4 cm. beneath the lateral pleura of an upper lobe. In such cases a zone of coarse emphysema separates the mass from the overlying pleura. On sectioning such a mass the knife creaks as though passing through tough leather but the gritty sensation often mentioned is rare unless obvious calcification is encountered. Deep within these areas of conglomerate fibrosis one frequently sees irregular zones of necrosis filled with inky fluid. There are no definite walls of a different color such as those surrounding a tuberculous cavity; the black fibrous tissue simply becomes granular and then liquefies. As there is no communication with a bronchus this debris remains *in situ.*

Massive fibrosis of this type replaces and obliterates all normal structures in the portion of lung involved. Along the irregular borders of such a lesion there may be included islets of dilated air spaces. Blood vessels are obliterated and thrombosis is common. The writer has seen four instances in which the main branches of the pulmonary artery were completely obstructed by organizing clots. All but the larger cartilaginous bronchi are likewise compressed and obliterated.

Microscopic Appearances

Microscopic examination of the *simple, discrete, silicotic nodule* reveals a characteristic picture. The lesion is composed of concentric laminae of thick, hyaline connective tissue fibers whose nuclei are thin and compressed. Around the outside of this main mass is a layer of more cellular connective tissue of variable thickness. Usually the latter is more or less infiltrated with phagocytes containing black carbon or other colored particles and the center of the hyaline nodule may also be pigmented. Contraction of the fibrous elements in the nodule causes some distortion of the air spaces in the immediate vicinity but there is little or no exudate. Variants of this picture are (1) central areas of necrosis in nodules produced by exposure to excessive quantities of very fine quartz in practically pure state and (2) the much more common tendency for several contiguous nodules to become surrounded by a common capsule, thus forming small conglomerate lesions.

Similar study of the *massive conglomerate areas of fibrosis* reveals a diffuse matrix of hyaline fibrous tissue in which nodular foci are more or less easily defined. The matrix sometimes presents an arrangement of fibers suggesting an origin in an organizing pneumonic process; in most cases there is no particular pattern. The necrotic foci exhibit simple degeneration of the scar without leukocytic reaction. This becomes understandable when it is noted that the blood vessels throughout the mass are either thrombosed or more or less occluded by endarteritis. The bronchi, when still patent, usually display variable amounts of chronic inflammatory reaction but most of the smaller branches are compressed beyond recognition.

It is not uncommon in persons that have been exposed to low concentrations of silica dust to find silicotic nodules only in the vicinity of old tuberculous scars with none in the other parts of the lungs. This observation, in contrast to the generalized distribution of the nodules in persons with no evidence of infection, has led to the hypothesis that the massive conglomerate types of fibrosis are the result of localized injury. The resultant lymph stasis would explain local retention of excessive quan-

tities of the irritant particles. This concentration would in turn cause more reaction of the tissues. If the infection was still active while dust was being inhaled the pneumonic process could organize to produce the form of scar tissue sometimes observed. The silica would then act upon newly formed connective tissue to produce the diffuse type of fibrosis of the matrix between nodules. Such theory has support in experimental observation where both tuberculous and nontuberculous infections have been observed to heal with resultant massive fibrosis of similar appearance. Other elements may influence the development of these massive lesions. All of them show dense pigmentation from accumulated nonsiliceous mineral particles. Whether this is merely a result of the local lymph stasis or whether such minerals actually initiate multiplication of connective tissue cells which are further stimulated and hyalinized by the associated free silica is not clear. Finally, the element of collapse incident to bronchial obstruction may play some part, although not a primary one, as this factor is not introduced until the fibrosis is well advanced. The writer is convinced that the most probable basis for massive conglomerate fibrosis is a healed infection which distorts the structure in a localized portion of the lung and disturbs its functional activity. Tuberculosis is the most likely kind of infection to occur in the upper parts of the lungs.

Roentgenologic Findings

Roentgenographic manifestations of silicosis, of course, vary with the character of the pathological process. In cases of *simple discrete nodulation* the diagnostic feature is the uniform distribution of the small, sharply defined shadows of nodules. Unless they are so distributed throughout both lung fields the presumption is that some other condition is responsible. In the very early cases the nodulation is fine and without stereoroentgenograms may be confused with an advanced stage of linear exaggeration. Watkins-Pitchford aptly compared the appearance of the latter to the leafless tree and when early nodulation supervenes, to the tree in bud. As the nodules increase in size and number, their shadows become larger and more numerous. Only the main branches of a tree in full leaf can be identified.

On inspecting a single film of an advanced case of nodulation there are so many small round shadows that it is hard to imagine that much uninvolved tissue is left. However, one should remember that the shadows of all the nodules in an organ from 4 to 9 inches in thickness have been projected onto one plane. Stereo-films will do much to dispel the impression of their number and an examination of the lung itself still more. Rarely are there more than eight to ten nodules

or more lobes with obliteration of the fissures. At other times a solid prism of such scar is discovered parallel to but 3 or 4 cm. beneath the lateral pleura of an upper lobe. In such cases a zone of coarse emphysema separates the mass from the overlying pleura. On sectioning such a mass the knife creaks as though passing through tough leather but the gritty sensation often mentioned is rare unless obvious calcification is encountered. Deep within these areas of conglomerate fibrosis one frequently sees irregular zones of necrosis filled with inky fluid. There are no definite walls of a different color such as those surrounding a tuberculous cavity; the black fibrous tissue simply becomes granular and then liquefies. As there is no communication with a bronchus this debris remains *in situ*.

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Complications

Relationship to Infection.—Silicosis definitely increases susceptibility to tuberculosis; it is frequently associated with chronic bronchitis that may lead to terminal bronchopneumonia. The incidence of lobar pneumonia is high in certain industries with silica hazards but when conditions like exposure to sudden and extreme changes in temperature have been corrected the pneumonia rate has fallen. Such experience suggests that factors other than the silicosis are responsible.

Tuberculosis

Incidence.—While a few writers have expressed skepticism there is little reason to doubt that silicosis predisposes to tuberculosis. Statistics from every industrial country in the world indicate rates for this infection in the silica industries four to twenty times that in adult employed males. Autopsy statistics reveal complicating tuberculosis in *60 to 75 per cent* of silicotic subjects. Animal experiments demonstrate that exposure to silica dust is unique in causing infection with tubercle bacilli of low virulence for various species, which progresses and produces chronic tuberculosis. The skeptics base their opinions on clinical impressions of isolated cases, but for reasons to be presented such evidence may be misleading.

Factors Affecting Incidence.—While there is more tuberculosis among silicotic subjects than others, the frequency of this infection varies with the *opportunities for contact* with the tubercle bacillus in particular communities. In a modern foundry in the city of Milwaukee where a program of control has been in operation for seven years, Sander now reports no excess of this infection. Among Rand gold miners in South Africa in 1937–38 only five new cases of tuberculosis were discovered on periodic examination of 28,414 men with silicosis. In the years 1917–18 there were 116 similar cases among 13,474 silicotics examined. Many other examples of such contrasts could be cited but they are hardly necessary. The point to bear in mind is that while prevalence rates may vary from community to community it is as necessary for silicotics to come in contact with the disease in order to

to the square inch in any plane of section. Emphysema is responsible for a variable amount of shadowless lung fields in the costophrenic regions. In moderately advanced cases the mediastinal shadow is broad and dense due to the enlarged lymph nodes; in the mature stages the density persists but the width of this shadow is again less because of the contraction of the nodes.

Cases of *massive conglomerate fibrosis* present a diagnostic problem because they simulate tuberculo-silicosis in which the infectious element is merely dormant and because sometimes they do not even reveal anything indicative of silicosis. The typical conglomerate case presents one or more dense massive shadows upon a background of generalized nodulation with variable amounts of peripheral lung fields black because of emphysema. Distortion of the diaphragmatic shadows and other evidences of chronic pleurisy are common. The massive shadows may radiate as large fans from the hilum into each lung field or they may involve the root of only one lung. Another common manifestation is the sharply defined block-like shadow located beneath the clavicle, crossing the anterior second and third ribs at right angles a few centimeters beneath the lateral pleura. Peripheral to it there is usually evidence of emphysema. Occasionally massive shadows occur in the lower thirds of the lungs but these are less common. Overexposed films fail to demonstrate much structure within these extremely dense areas and even the foci of anemic necrosis lack sufficient definition to be visualized.

The contraction of these sclerotic masses, fixed to the chest wall by pleural adhesions, pulls much of the lung tissue upward and in so doing the discrete nodules in the lower lung are brought into close proximity to the massive lesion. Coincidently the air spaces in the lower lungs become overdistended to keep the pleural cavity filled. The combination of compensatory emphysema and a contracted lung may completely obscure the shadows of the discrete nodules so that they fuse with that of the large mass nearby. As a consequence the film may reveal only the massive shadows, emphysema, and chronic pleurisy with no discrete shadows to suggest the silicotic origin of the condition. These cases present a most difficult problem in diagnosis.

its borders the air-containing lung is invaded by a very chronic, fibroid type of tuberculosis. There may be a few clusters of isolated tubercles in the lower lung but usually bronchogenic and hematogenous extensions are rare. Similarly complications in the larynx, intestines and other organs are most exceptional. This very chronic form of tuberculosis is the usual one in silicotic subjects and since both its pathological and clinical manifestations are atypical it properly deserves its special name of tuberculo-silicosis.

Quite exceptionally tuberculosis may behave in a typical manner in persons with minimal or very old silicotic nodulation. In such cases a chronic apical focus progresses slowly and finally excavates with resultant bronchogenic or hematogenous dissemination through the lungs and perhaps extrapulmonary complications.

Roentgenographic Appearances of Tuberculo-silicosis.—These are often indistinguishable from those of massive conglomerate fibrosis on first examination. *Annual films*, however, may demonstrate a gradual extension of the process. In many cases the time ultimately arrives when the activity of the infectious element is manifested; cavities may then be visualized and progression becomes much more rapid. Death may be anticipated within a period of two or three years. The rarer typical tuberculosis on a background of silicotic nodulation presents no unusual features.

Clinical Picture in Silicosis

One of the most characteristic features of simple, discrete, nodular silicosis is the paucity of symptoms and clinical signs in comparison with the extent of the roentgenological manifestations. Many subjects are entirely unaware of their condition until it is revealed by a routine roentgenogram. They continue to perform hard physical labor with no complaints and no diminution of output. Only severe and unusual exertion demonstrates some *dyspnea*. Some, on the other hand, will report constriction or burning sensations in the chest. Not infrequently there is an *unproductive cough*, probably due to bronchial irritation and not to changes in the lung proper. It seems probable that certain susceptible individuals may have symptoms even in minimal stages of the disease although this subject needs further investigation. The stethoscope often detects a *harsh respiratory note* and expiration is apt to be prolonged. In this type of disease chest ex-

develop tuberculosis as for other subjects. The presence of silicosis merely enhances the probability of effectiveness of such contact.

In groups of persons exposed to silica dust the incidence of complicating infection increases with the *severity of the reaction.* For one large group of 2612 miners, Cummings reported the following rates per 100,000:

No evidence of dust reaction	0.5
Linear exaggeration, 1st degree	1.0
Linear exaggeration, 2nd degree	2.0
Silicotic nodulation, 1st degree	6.0
Silicotic nodulation, 2nd degree	12.0

The frequency of tuberculosis in silicotics also increases with *age* which has led to the belief that most of the infections are of exogenous origin. This is true in many instances, but an appreciable number result from reactivation of preexisting latent foci of reinfection type disease. The probabilities of reactivating a so-called primary or Ghon tubercle are much more remote. While this possibility has been demonstrated experimentally in animals, annual reexamination of large groups of human subjects has demonstrated the great rarity of its occurrence. The calcified or fibrous parenchymal tubercles of the primary complex remain unchanged through years of exposure to silica dust although in some countries men with such lesions are rejected on the preemployment examination. In the United States the general practice is to admit them unless, of course, the primary focus shows evidence of recent activity.

Pathological Anatomy.—The pathological anatomy of tuberculosis in the silicotic subject is usually materially different from that in other individuals. In its commonest manifestation as *tuberculo-silicosis* it may be almost indistinguishable from the massive conglomerate form of simple silicosis, already described. Many sections may be necessary to disclose an isolated focus of caseation or a small tuberculous cavity. When such an area is exposed it is usually recognized easily by the gray-yellow color of the caseous matter which offers sharp contrast to the surrounding black fibrous tissue. In some instances the microscope must determine whether the infectious process is still active and even this method may require inspection of several square inches of section for the foci of activity may be few and far between. More often, however, the tuberculous complication is obvious at the time of autopsy. In 60 per cent of the conglomerate cases, large cavities have destroyed much of the massive scar and about

corroborative history must be obtained. This involves a complete record of a man's occupational life, including not only the plants at which he worked, but the kind of job and the materials used. The physical examination is important for two reasons: (1) It may show almost complete absence of abnormal signs, which, in conjunction with the extensive roentgenographic changes, is almost pathognomonic of silicosis; and (2) it may reveal evidences of activity of an infectious process. As already indicated, the most difficult diagnostic problem is the determination of the latent element of infection in a lesion of massive conglomerate type. Only repeated examination can settle this question.

Other Complications of Silicosis.

The effect of silicosis upon the circulation is a subject that has been discussed without definite conclusion. Both silicosis and heart disease are most frequent in mature adult life. Many believe that obstructive fibrosis in the lungs results in *cor pulmonale* with characteristic hypertrophy of the right side of the heart. If this result does follow it is probably limited to cases of massive conglomerate silicosis. Discrete nodulation seems to produce little anatomical change in the pulmonary blood vessels. But even with conglomerate disease cases are rare in which only the right side of the heart is affected. Most of them have generalized *cardiovascular lesions* which might easily have originated independently. Obstructive fibrosis in the lungs places an added burden on the overworked heart but the writer questions whether it is a primary cause of heart disease.

While some authors have claimed that soluble silica, liberated in pulmonary lesions, circulates through the body to poison other tissues, there is nothing to support this purely hypothetical reasoning. Any excess of *nephritis* that may occur can be explained by the higher incidence of arteriosclerosis at the age periods when silicosis is common. Silicotic involvement of lymph nodes at the head of the pancreas is a regular finding and occasionally nodes along the abdominal aorta are involved. Only once has the writer known them to cause symptoms.

pansion and the excursion of the diaphragm may be somewhat limited.

In the presence of *massive conglomerate fibrosis* the picture is different. These men are definitely short-winded. Although many of them continue to work, their production is much below par. Unusual exertion precipitates an attack of severe dyspnea from which they recover slowly. They frequently suffer pleuritic pain and cough, which is particularly troublesome in the morning. In some it is severe enough to precipitate vomiting. Theirs is the picture of advanced emphysema with the physical signs of that condition.

When the conglomerate lesion is due to an unhealed tuberculous infection *toxic symptoms* are so late in making their appearance that diagnosis is difficult. Not until the terminal breakdown do these cases manifest symptoms ordinarily associated with tuberculosis. Before that time they are short of breath but well nourished or even overweight from restricted activity. They have no fever, loss of appetite, or increase in sedimentation rate. Tubercle bacilli do not appear in their sputa. It is necessary to follow them carefully year after year to note the first hint of symptoms or the development of a *positive sputum.* On occasion, monthly guinea-pig tests may demonstrate the presence of tubercle bacilli followed by many negative specimens. Usually, however, the sputum remains positive after the organisms finally appear. For economic as well as medical reasons most of the closed cases are better off if they are allowed to do some work compatible with their strength. If put on rest treatment they are discontented and their dyspnea seems to become more severe. But they should not be neglected; as soon as any evidence of activity, and particularly a positive sputum, makes its appearance, they must be removed from contact to protect their fellow workmen.

Diagnosis of Silicosis

Diagnosis depends upon *a history of adequate exposure* in an industry with a free silica hazard, a *chest roentgenogram* showing a shadow pattern characteristic of this disease, and *physical signs* of the nature already described. The film often suggests the presence of silicosis but to establish a diagnosis

corroborative history must be obtained. This involves a complete record of a man's occupational life, including not only the plants at which he worked, but the kind of job and the materials used. The physical examination is important for two reasons: (1) It may show almost complete absence of abnormal signs, which, in conjunction with the extensive roentgenographic changes, is almost pathognomonic of silicosis; and (2) it may reveal evidences of activity of an infectious process. As already indicated, the most difficult diagnostic problem is the determination of the latent element of infection in a lesion of massive conglomerate type. Only repeated examination can settle this question.

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Prognosis

Prognosis in *uncomplicated, discrete, nodular silicosis* is good. In the absence of infection such lesions reduce the reserve capacity of the lungs but do not seriously interfere with ordinary work. Persons with simple silicosis should be kept under observation and given an annual x-ray examination to detect early evidences of tuberculosis. In the absence of this complication their life expectation is not greatly impaired.

Massive conglomerate silicosis is a more serious condition. It causes disability in its own right and it is hard to differentiate from tuberculo-silicosis in an inactive phase. Men with small conglomerate lesions often work with little difficulty but after exertion dyspnea is much more obvious than in those with the discrete form of the disease. The large conglomerations are usually incapacitating because of associated emphysema.

Tuberculosis in any form is a serious complication of silicosis as it is responsible for most of the disability from this disease. Detected early and promptly subjected to treatment it need not terminate fatally in the cooperative patient. The advanced tuberculo-silicotic lesions are another matter; those in whom there is an element of active infection quite regularly progress and although death may occur from other causes, many ultimately succumb to their infection.

Treatment and Disposition of Cases

There is no known treatment for silicosis; the condition must be prevented by control of the dust in the environment and by the proper selection of persons who are to be employed. Good plant housekeeping, the use of water, adequate general ventilation and local exhaust systems are usually sufficient to maintain safe concentrations of dust in the air of working places. *Medical control* involves a preemployment examination to exclude persons with tuberculous lesions from exposure to silica dust and periodic examinations to detect evidences of disease in those already employed.

Independent observations by Robson, Denny, and Irwin in Ontario, and by the Saranac Laboratory in this country have demonstrated that *aluminum and certain of its compounds*

will prevent the development of silicosis. The Canadian observers obtained their results with finely divided aluminum powder. The Saranac Laboratory's experiments were made with the hydroxides of aluminum. Immature silicotic lesions are aborted and regress, but fully developed nodules are not affected. To be effective, a large quantity of the inhibitor must reach the same location and probably the same phagocytic cells that contain the quartz particles. Chemical reaction results in a coating of the silica whose toxic effects are completely neutralized. Experiments are now in progress at the Porcupine Silicosis Clinic in Timmins, Ontario, to discover whether aluminum inhalation therapy has any influence upon symptoms. As a prophylactic measure aluminum inhalations might be effective, but difficult of application to a large group of workmen. There is no reason to believe that it can ever be substituted for engineering methods to reduce atmospheric concentrations of dust.

The *disposition of employees* in whom the periodic examination discloses different manifestations of pulmonary disease depends upon a number of factors: the effectiveness of dust control in the plant, the condition and age of the man, the opportunities for transfer to other jobs, and so on. Medical recommendations in each case must be particularized and will depend upon a thorough study of the individual. In general, men with simple discrete nodulation may continue at their regular work in a plant with a good program of dust control. Exception should be made in the case of the young employee who manifests signs of early silicosis after a short exposure. He is probably more susceptible than others and should be transferred to another job, but there is no medical reason why he should stop all work. The same may be said of the case with a small focus of conglomerate fibrosis without much dyspnea. More advanced cases of the same character seem to have less dyspnea if they are allowed to do light work instead of being laid off with no exercise. Management, however, is often embarrassed to find enough jobs of this character in the heavy industries like mining.

Of course all of these men require *constant observation* to detect the earliest evidence of activity in an infectious com-

plication. Open tuberculosis means segregation for the protection of the rest of the group; early tuberculosis should be given full sanatorium treatment, and recovery is quite possible in the cooperative patient. The chronic tuberculosilicotic is best cared for on a modified regimen of exercise. Ultimate recovery is rare.

RAPIDLY DEVELOPING SILICOSIS

A rare and atypical manifestation of silicosis has occurred in a few groups of persons exposed to excessive concentrations of very pure and very fine quartz dust. This condition was first identified in persons manufacturing and packing abrasive soap powders and it was assumed that free alkalies associated with the silica caused rapid solution of the inhaled quartz. Animal experiment finds no justification for this hypothesis and subsequent observation has demonstrated similar cases in sandblasters working in enclosed tanks and certain tunnel workers whose exposure included no alkalies. After periods as short as eighteen months some of these operatives have developed severe dyspnea. *Chest roentgenograms* reveal only a fine diffuse haziness throughout the lung fields with no suggestion of the classical nodulation. A few have died within a year or so and a number of autopsies have been obtained. Many of them showed a *complicating tuberculosis*, and in most of the others the cause of death was a *nonspecific bronchopneumonia*. But apart from these infectious lesions, all of the lungs have presented a generalized induration which, in gross, suggested an organizing pneumonic process, but on microscopic examination was revealed as a diffuse silicotic reaction. Irvine aptly described it as a "dust pneumonia."

Practically the same picture is seen in guinea pigs exposed to excessive amounts of pure quartz dust of very fine particle size. Innumerable silicotic nodules of microscopic dimensions occur throughout the walls of the pulmonary air spaces. There is also a generalized proliferation of all connective tissue elements in the lungs and the formation of plugs of similar tissue within some of the alveoli. Tracheobronchial lymph node reaction is minimal. Apparently the lung is so nearly

overwhelmed with the large amount of a potent irritant that the lymphatic system is entirely inadequate to remove it. Reaction begins simultaneously throughout the functional portions of the organ. However, even under such circumstances, time is essential for the quartz to produce any gross change. In guinea pigs nothing can be seen for the first six months of exposure. Therefore it seems ill advised to describe this condition as an "acute" silicosis.

The *diagnosis* depends upon the history of an unusual exposure which must be verified in all essential details, upon the roentgenogram with its barely identifiable haziness and the clinical picture of marked dyspnea. These cases need careful protection against infection.

ASBESTOSIS

Pathological Anatomy

The characteristic features of well marked asbestosis are (1) *diffuse, non-nodular fibrosis* involving ill-defined portions of the parenchyma of the lung, (2) moderate sized *emphysematous blebs* often located in fibrous strands beneath the lateral and interlobar pleura, and (3) *adhesive fibrous pleurisy*. Such a lung has a doughy consistence but can be partially collapsed by moderate pressure.

The diffuse involvement is frequently associated with fibrous thickening of the interlobular septa so that these structures are clearly demarcated on the cut surface of the lungs. In the center of each lobule one usually finds an ill-defined collection of gray dust pigment; in sections cut in a proper plane the fanlike branches of a terminal bronchiole are seen to enter the pigmented area. The emphysematous blebs often occur in rows roughly parallel to the pleura. Most of them are less than 5 mm. in diameter with smooth, glistening gray walls; sometimes they are much larger and project through and above the thickened pleura as bullae. The tracheobronchial nodes are blue-black in color, small and moderately firm.

Microscopic sections of the lungs reveal a diffuse fibrosis, not as dense or hyaline as in silicosis. It extends from the terminal bronchioles into the parenchyma, replacing many but not all of the air spaces in a lobulated plane. Animal experiments and the few cases of early disease in man that have come to autopsy reveal that such fibrosis begins about the terminal bronchioles and slowly spreads into the periphery of the lung. Apparently most of these fibrous foreign bodies are caught in the respiratory bronchioles whose walls are irregular because of lateral alveolar pouches. Just proximal to these structures the lining epithelium of the bronchial tree changes from ciliated to low columnar cells, another factor which may influence retention. As fibrosis develops in the walls of these bronchioles the lateral alveoli are closed or stretched so that the internal contour of the tube becomes smooth. Subsequently inhaled fibers now pass deeper into the lungs and there cause more fibrosis. Patent air

spaces in the midst of a fibrous zone are apparently supplied by uninvolved bronchioles outside the plane of section. It is probably these air spaces which dilate after being cut off and appear as emphysematous blebs.

A characteristic feature is the presence of large numbers of *asbestosis bodies*. These structures result from the deposition of albuminous material and iron upon the surface of the inhaled fibers. They vary in size and shape from minute globules 1 micron or less in diameter to haustrated rods 5 to 60 or more microns in length. They are golden-yellow in color and exhibit many bizarre forms. Most have swollen, club-shaped ends and many show beading or smooth, lateral projections. They occur in clusters within air spaces or widely scattered throughout the scar tissue.

Roentgenologic Findings

Roentgenographic appearances of moderately advanced, uncomplicated asbestosis are much less obvious than the anatomical changes would suggest. Inspection of the film reveals a light, diffuse haziness overlying the lower third of both lung fields. Evidences of pleurisy may or may not be visualized. As the fibrosis matures the haziness is more pronounced until it reaches the so-called "ground glass appearance" which obscures all lung markings. The upper thirds remain relatively clear. The failure of the fibrosis to cast a more dense shadow is probably due to the relatively large number of patent air spaces persisting throughout it. As histological examination reveals as much reaction in the upper lungs as in the lower thirds, it is inferred that the distribution of the x-ray shadows is due to the greater thickness of the lower lung. Very advanced cases may show a fine stippling and a certain amount of reticulation superimposed upon the ground glass background. In such cases pleuropericardial adhesions are responsible for the so-called "porcupine heart shadow."

Relationship to Infection

American surveys reveal no such general excess of tuberculosis as occurs in the free silica industries. In England much more infection has been reported and autopsy statistics from all countries reveal many instances of *terminal tuberculosis.* Animal experiments demonstrate no special tendency for tuberculosis to progress upon a background of asbestosis. The infections frequently heal, accentuating the fibrosis provoked by the dust. It seems probable that socio-economic factors

may outweigh those of the dust and that selection has influenced the incidence in the postmortem cases. Persons with asbestosis who contract tuberculosis are apt to be sent to sanatoria where autopsies will be secured because of the special interest in the occupational origin of their disease. Those dying elsewhere are less apt to come to autopsy.

Course of the Disease

The course of the disease is somewhat obscure as most of the patients who could be followed continued to work with more or less dust exposure in spite of the excellent programs of dust control in most American factories. Cases that were quite well developed when first observed now reveal more intense x-ray shadows; those with little change at the outset seem to remain in approximately the same condition. In animals no progression occurs after complete cessation of exposure. Any fibrosis originally present tends to become denser but it does not increase in area. Asbestosis bodies disappear between two and three years after an injection of asbestos into the lungs of guinea pigs.

Clinical Picture

A case of asbestosis exhibits dyspnea which seems entirely out of proportion to the severity of the roentgenographic changes. These patients are very short of breath, have a dry unproductive cough, and are said to have a somewhat bluish color. The latter symptom is not invariable. Signs of cardiac injury are not generally elicited. Occasionally asbestos bodies can be detected in the sputum but they rarely appear in the absence of associated infection.

Complications

As already indicated *tuberculosis* may be superimposed on this condition, but there is little to indicate an excessive prevalence. Bronchopneumonia is a commoner cause of death. Reported autopsies from various countries have demonstrated ten cases of *primary bronchogenic carcinoma* among persons with asbestosis but in comparison with the number exposed to this dust this incidence would not appear at all surprising.

The character of the pulmonary fibrosis would seem to be ideal to create a *cor pulmonale* because large amounts of capillary bed are obliterated. However, neither clinical nor pathological evidence seems to indicate a high frequency of cardiac involvement.

A complication of the occupation although not of the pulmonary disease is the so-called *asbestos corn* on the skin. This is a localized focus of chronic inflammation provoked by relatively coarse splinters of the mineral that may penetrate into the subcutaneous tissue. No asbestosis bodies are formed in these lesions.

Diagnosis

Diagnosis depends upon a history of exposure to dust of asbestos fibers, characteristic chest roentgenograms and physical findings. Dust exposure occurs usually in fabricating plants where fireproof textiles, brake linings, and similar materials are manufactured, or among those using asbestos fiber for insulating purposes. Strangely enough experiment has demonstrated that the longer fibers are much more dangerous than very finely powdered asbestos. This probably explains the absence of the condition at the mines where, in formerly very dusty plants, the mineral was ground, separated, and the finest products collected for insulating purposes. An average exposure of about eight years seems necessary to produce roentgenographic evidence of asbestosis.

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LEAD ABSORPTION AND LEAD POISONING

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DESPITE the availability of sound and well established methods for recognizing and preventing dangerous industrial lead exposure, there is still an unnecessarily high incidence of lead poisoning among industrial workers. Furthermore, despite the existence of generally reliable diagnostic criteria, confusion and uncertainty often enters into the consideration of a suspected case of plumbism, whether the question at issue is the proper care of a sick man, the hygienic status of a plant, the granting of compensation, or the outcome of litigation. For these reasons, one may be justified in reviewing the hygienic and diagnostic problems that arise from the use of lead compounds in industry.

THE EVIDENCES OF OCCUPATIONAL LEAD ABSORPTION

The existence of occupational lead exposure can usually be recognized by a survey of the materials and activities in an industrial plant. The general order of magnitude of the exposure can be estimated by the determination of the lead content of the atmosphere of working spaces, by the use of standard methods.[1, 2] By such means it is usually possible to determine the degree of the occupational hazard and the extent of the need for preventive and precautionary measures. Indeed if the lead content of the atmosphere of workrooms in the lead trades were maintained generally within the limits now recognized as safe, occupational saturnism, from any other cause than accidents and the unforeseen effects of changes in plant operations, would cease to occur. However, so long as the hazards of many plants are not under such

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control, and so long as opportunities for accidental and inadvertent lead exposure exist in industry, it will be necessary to provide medical supervision which will be on the alert for the signs of potentially dangerous lead absorption. The physiological evidences of lead absorption above the normal level should be clearly understood, therefore, for their importance not only in industrial hygiene but also in general medical and medico-legal practice.

Urinary Lead Excretion

The earliest sign of elevated lead absorption, and one which fortunately is specific for lead alone, is found in an increased rate of urinary lead excretion.[3] The demonstration of a small increase requires careful procedures for the collection of samples and detailed knowledge of the physiological factors concerned with the urinary excretion of lead.

Various published statements have appeared to the effect that the urinary lead fails frequently to reveal the extent of lead absorption, that the results obtained on urine samples are too variable, and that the blood, more constant as to its lead content, should be used for obtaining analytical information. These conclusions have sprung from inexperience or from the use of inadequate methods for the collection and analysis of samples. It is true that urinary samples of small volume obtained at random are subject to considerable variation in their lead content. In individual cases, the latter varies chiefly with the urinary volume during the period of collection, *i.e.*, if the urine is concentrated the lead concentration is relatively high, if dilute from high water intake or diuresis, the lead concentration is relatively low. This factor can be controlled, in the case of small volumes, by *proper selection of the time of sampling* so as to avoid extremes of water intake and output; it can be eliminated altogether by collecting one or more liters of urine, making sure that no unusual quantities of liquid are taken to speed up the collection of the sample.

Equally important is the *avoidance of contamination* of urinary samples, and the smaller the sample the greater must be the care in this respect. Urine samples collected in the usual type of washrooms or medical quarters in manufactur-

ing plants, or obtained by customary hospital procedures, or, in fact, secured by any other than by precise methods controlled by the examiner, are not only valueless but grossly misleading as to their lead content. Lead is ubiquitous, and it is difficult under the most favorable circumstances to avoid all sources of contamination.

Numerous case reports in current journals include analytical data on the urine which by mere inspection can be discarded as erroneous. In some instances the quantities found bear no relation to the conditions of exposure known or believed to have existed, and in others they are entirely beyond the maximal limits of urinary lead excretion. In this connection it should be pointed out that a urinary lead concentration in excess of 0.5 mg. per liter is a rarity, that concentrations higher than 0.3 mg. per liter are associated only with grossly dangerous conditions of lead exposure and absorption, while values exceeding 0.20 mg. per liter do not occur in any other than highly concentrated urines without a definite and significant exposure to lead such as is associated with the admittedly hazardous lead trades.

Urinary Lead Concentration.—In practice, one must depend upon results expressed in terms of urinary lead concentration rather than on the basis of lead output per unit of time. The urinary lead concentration can always be determined, but measurement of the excretory rate on a time base is not always feasible, and over short periods of time it has no advantage over random sampling. Moreover, the extensive data on the urinary concentration of lead under a wide variety of conditions, have given it a practical significance which is more certain than is that of the lead output per day. For comparative purposes, therefore, analytical results should always be expressed in terms of concentration, and when possible, on a time basis as well.

Examination of Blood

The greater stability of the blood, with respect to its lead concentration, from hour to hour, as compared to the urine, is unquestioned. On the other hand the change in the blood concentration as a response to lead absorption is proportionately less than that of the urine, the result being that the effects of exposure are more easily demonstrated by the urinary lead concentration than by that of the blood. The chief

advantage of the analysis of the blood, for diagnostic purposes, lies in the fact that it requires no manipulation on the part of the person examined. If proper precautions are taken by the examiner, therefore, no factor of contamination need be considered. Blood samples, however, must be taken with the utmost precaution in a dust-free room, by means of specially fabricated needles, into specially cleaned containers. The minutest details of handling are of the same importance, though of different type, as those used in the maintenance of aseptic technique in surgery. Lead, like minute living organisms, enters into samples through the air by means of contact with any save the most meticulously purified water, reagents, glassware and other equipment.

Examination of Feces

The value of the analysis of the feces of groups of exposed workmen as a means of determining the relative magnitude of their lead exposure by ingestion and inhalation has been pointed out elsewhere.[4] By virtue of the fact that a considerable proportion of dust in the respired air is caught in the upper respiratory tract and subsequently swallowed, the quantity of lead appearing in the feces provides a somewhat crude but highly useful measure of the exposure for the period represented by the fecal sample. The lead in the feces is predominantly and, indeed, almost wholly ingested or inhaled (subsequently swallowed) lead under any other than the most unusual circumstances. It is probable that considerable quantities of lead may be secreted into the alimentary tract for a short period following the absorption of very large amounts of lead, but, in the main, the true alimentary excretion of lead is quite small. It is probably of little greater magnitude per day than that excreted in the urine, and it may be even less under certain circumstances.[3, 5]

This true alimentary lead excretion is completely masked by the much larger quantity of unabsorbed lead that is ingested with the food under ordinary conditions. It is quite impossible to determine its magnitude or even its occurrence when lead exposure occurs through inhalation of dusts, for under these conditions it is an exceedingly minute fraction

of the fecal lead. For these reasons the fecal lead, as such, bears no significant relation to the lead content of the body of an individual, and indicates nothing with respect to absorbed lead. As a means of estimating the lead absorption of either groups or individuals for diagnostic purposes it is wholly worthless.

Other Evidences of Lead Absorption

Other signs of lead absorption above normal levels are: (1) changes in the quantity and distribution of basophilic material within the erythrocytes, and (2) the appearance of punctate deposits of lead sulfide in certain mucous membranes, especially in the margin of the gum tissue. Neither of these signs is indicative of lead intoxication. Both occur in entirely healthy persons, except that the gingival lead line occurs only where sulfide is present in the gum tissue and, therefore, it is usually associated with a low-grade gingivitis. It is rarely seen in the gums of children, for example, among whom chronic gingivitis is uncommon.

Punctate Basophilia, or "Stippling" of the Erythrocytes.—Within certain limits, stippling is of normal occurrence in the human blood. In examining the blood of some thousands of apparently normal healthy adults free of occupational lead exposure, my associates have found such erythrocytes in numbers ranging from one or two up to as high as six thousand per million erythrocytes. Some 6 per cent of the group showed one thousand or more per million erythrocytes, while the mean figure for 784 persons was 339.18 ± 9.72 per million erythrocytes.[6] The number of such stippled erythrocytes in the blood shows little or no change with small increments of increased lead intake, but at higher levels of exposure and absorption their number in the circulating blood tends to increase. Considerable variation in the degree of individual response is observed, and fairly wide variations occur from day to day; but with increasingly severe conditions of lead exposure there is a definite trend toward increasing numbers of stippled erythrocytes in the blood of exposed workmen, if comparisons are based on groups rather than individuals.[7] These facts are responsible both for the usefulness of regular microscopic examinations of the blood of workmen as a means of estimating the severity of occupational lead exposure, and for the inadequacies of such measures for diagnostic purposes in individual cases. Suffice it, for present purposes, to point out that hazardous exposure to lead compounds is associated with the appearance of definitely abnormal numbers of basophilic erythrocytes in the blood of a considerable proportion of exposed workmen.

Lead Line on Gums.—A "lead line" may appear in gum margins which are the site of bacterial invasion whenever the lead content of the involved tissues is sufficiently elevated. We have observed the appearance of a faint blue line at the edge of an infected gingival area in one person whose blood contained lead only to the extent of 0.05 mg. per 100 grams. Easily identified lead lines signify somewhat higher levels of lead absorption, and in general, they are indicative of hazardous lead exposure. Nevertheless, obvious deposits of lead sulfide are seen in the gums of persons with no demonstrable symptoms or signs of intoxication. They must be

differentiated from similar deposits resulting from the precipitation of other metallic sulfides, notably of bismuth, and they must not be confused with the normal pigment of Negroes and correspondingly dark-skinned peoples. The former differentiation is sometimes provided by the medical history of the person in question, but may require analysis of the blood or urine or both; the latter can usually be made by careful study of the locus and appearance of the pigment. The natural pigment is rarely found in the gum tissue on the lingual side, while a favored site for the first appearance of lead line is in the extreme lingual edge of the gum opposite the bicuspids and molars, especially in the lower jaw. The bluish purple line of gingival congestion may be taken for lead line by the inexperienced, and especially if examination is made without expression of the blood by means of a transparent applicator (such as a glass slide). More frequently, the stained or discolored surface of a tooth just visible beneath a thin layer of gum tissue is mistaken for a lead line. The differentiation is not always easy and resort must sometimes be had to the use of a hand lens, or even to biopsy followed by microchemical or spectrographic analysis.

THE RECOGNITION OF DANGEROUS LEAD EXPOSURE

The differentiation of *harmless* from *toxic* human lead exposure in any final sense must be based upon adequate means for detecting the earliest or the slightest toxic effects of lead upon the human organism. So much has been said and believed about the insidious and unpredictable effects of lead absorption, that it is difficult to approach the subject in a realistic manner. Admittedly, in the case of lead, as well as of most elements and compounds whose physiological behavior cannot be defined in complete detail, it is well to maintain openness of mind and acuity of observation, with respect to remote effects upon general health, well being, and length of life, that may accrue to individuals and groups as the result of prolonged exposure.

Nevertheless, careful clinical study of workmen under known conditions of lead exposure over periods of years, has provided convincing evidence of the validity of certain *working principles* on which modern hygienic practice in the lead trades is based. These principles, stated in general terms, are as follows: (1) that the toxic effects of human lead absorption can be detected and identified as a well defined clinical syndrome despite some variability in details; (2) that persons who do not develop lead poisoning in recognizable form, suffer no demonstrable injury to their health or well-being as a consequence of their absorption of lead; and (3)

that dangerous lead exposures can be differentiated from safe on a quantitative basis. Each of these points merits careful consideration.

Lead Intoxication (Plumbism)

The conviction or the acquittal of lead as the causative factor in the illness of industrial workers is relatively easy if the conditions of exposure to lead are well known and if such illness is subjected to adequate medical study at the time it develops. For this reason the attending industrial physician should have considerable advantage over other physicians who may be consulted. The latter usually lack precise information as to the exposure, and, therefore, must either accept hearsay information on that score, or resort to indirect means for determining the facts, *i.e.*, laboratory evidence of lead absorption. Such indirect evidence can be obtained satisfactorily only if the patient is seen early in the course of his illness. Unfortunately a physician is often consulted some time after the subsidence of the episode of intoxication, and in such case he must depend, for this and all other data, on sources that are likely to be inadequate and are sometimes unreliable.

In view of the differences of opinion that arise out of these circumstances it seems advisable to discuss certain major aspects of the diagnosis of lead poisoning from the viewpoint of the general physician, whose knowledge and judgment, as compared with that of the industrial physician on the scene, must be in keeping with the more difficult problem with which he is presented. In this way the scope of the discussion will extend somewhat beyond the toxic effects of lead absorption as an indication of hazardous lead exposure. It is to be hoped that its usefulness will be enhanced thereby and that it will not miss its primary goal.

The diagnosis of plumbism is based upon (*a*) a history of *significant* lead exposure, (*b*) the presence of an illness or injury which is consistent with the known clinical picture of lead intoxication, and (*c*) certain corroborative laboratory findings. The first and last items of this triad might well be combined into one in practice, since they lead by different

means to the same end, that of implicating or excluding lead as the specific toxic agent, and in that role the one supplements and in some instances substitutes for the other. However, they can better be discussed separately.

A History of Lead Exposure

The history of lead exposure as it is commonly recounted to the physician is likely to be worthless and is often misleading, not so much because it may be intentionally colored, as because it gives an inadequate basis for determining the severity of the exposure. *Detailed knowledge* of industrial procedures and precise information as to the conditions existing in a specific plant or operation, are absolute essentials for the interpretation of such an history. If the examiner's experience in industry is extensive, he may sometimes elicit the information he requires by careful questioning. Otherwise, he will be well advised to use the history merely as an indication that lead absorption is a possibility in the case, and seek information as to the extent of the exposure through other channels. The assumption that employment in actual or supposed lead trades involves hazardous lead exposure is the most frequent cause of erroneous diagnoses of lead poisoning in industrial workmen. It is one which can be avoided only through the general acceptance among physicians of the fact that lead exposure has no meaning in the hygienic or diagnostic sense unless it results in the absorption of toxic quantities of lead.

Clinical Picture

The clinical picture of lead poisoning is illustrated in part by the data obtained from a series of thirty proved industrial cases that have come to us before the subsidence of an acute episode of intoxication. Table 1 gives the symptoms as recorded, in the order of decreasing frequency of occurrence, and indicates the number of instances in which the specific symptom was not mentioned in the record. Table 2 lists the physical signs in similar manner and in addition shows when the sign was recorded as absent. Table 3 shows the chief complaint at the time of the examination. None of these cases was seen at the onset, and several were seen late in the toxic

episode, the average time between the onset and our examination being thirty days. The series, therefore, is characteristic of cases of active industrial plumbism as they occur in general or consulting practice in diversified industrial centers.* From these data it is apparent that the *physical signs* found in lead intoxication, with the exception of the gingival lead line—which as indicated previously is not a sign of intoxication, but only of absorption—are rather few in number and are quite nonspecific.

TABLE 1

FREQUENCY OF OCCURRENCE OF SYMPTOMS IN THIRTY CASES OF LEAD POISONING STUDIED BEFORE SUBSIDENCE OF AN ACUTE EPISODE

Symptoms	Recorded as Occurring	No Data
Weakness	30	0
Weight loss	27	3
Constipation	25	5
Colic	24	6
Anorexia	23	7
Abdominal pain	23	7
Arthralgia	21	9
Lassitude	17	13
Frequent use of cathartics	17	13
Generalized aching	16	14
Vomiting	16	14
Nausea	15	15
Insomnia	13	17
Headache	12	18
Metallic taste	12	18
Generalized stiffness	10	20
Excessive dreaming	9	21
Excessive salivation	8	22
Localized myalgia	8	22
Vertigo	8	22
Nocturia	5	25
Numbness of extremities	5	25
Muscle cramps	4	26
Impotence	3	27
Visual disturbances	3	27
"Nervousness"	3	27
Convulsions	2	28
Dysphagia	2	28
Ataxia	2	28
Stupor or coma	2	28

The *subjective complaints*, on the other hand, are numerous. They too are nonspecific, but case study shows that they

* Compare the symptoms and signs with those described by Russell and his associates[8] and Dreessen and others[9] in their studies of workmen in the storage battery industry.

group themselves in such a way as to reveal the patterns of the toxic process. Obviously, there is a general intoxication in which *weakness, loss of weight,* and *lassitude* are prominent. Associated with these, and producing much the commonest

TABLE 2

FREQUENCY OF OCCURRENCE OF PHYSICAL SIGNS IN THIRTY CASES OF LEAD POISONING STUDIED BEFORE SUBSIDENCE OF AN ACUTE EPISODE

Physical Signs	Present	Absent	No Data
Lead line.	20	10	0
Pyorrhea	20	5	5
Extensor weakness of wrists	17	9	4
Malnutrition	12	12	6
Abdominal tenderness	11	14	5
Hyperactive biceps reflex	10	12	8
Hyperactive patellar reflex	9	18	3
Tremor	9	12	9
Pallor	8	11	11
Sensory disturbances	7	17	6
Excessive salivation	5	14	11
Myoedema	4	5	21
Joint tenderness	4	20	6
Eyeground changes	3	20	7
Stupor	2	28	
Convulsions	2	28	
Delirium	1	29	
Coma .	1	29	
Bilateral wrist-drop	1	29	

clinical picture, is a *disturbance of the gastro-enteric tract* of which constipation, anorexia, and abdominal discomfort or actual colic are the regular manifestations. There may be additional symptoms arising from *neuromotor abnormalities,* and from *intoxication of the central nervous system.* The

TABLE 3

CHIEF COMPLAINT AT TIME OF EXAMINATION IN THIRTY CASES OF LEAD POISONING STUDIED BEFORE SUBSIDENCE OF AN ACUTE EPISODE

Complaint	Frequency
Abdominal pain, cramps or colic	22
General weakness	4
Joint pain	3
Nausea and vomiting	1

variations in the severity of these associated complaints give rise to the three main clinical types of saturnism, the gastroenteric, neuromuscular, and cerebral. Physical signs, although meager, accompany these symptoms, and by their type and importance tend to establish the character of the intoxication.

Thus, if the only complaints are referable to the gastro-enteric tract, the physical signs are likely to be limited to pallor, malnutrition, loss of weight, and abdominal tenderness on examination, or the visceral signs of acute abdominal pain. If the neuro-motor symptoms are predominant, there will be concomitant signs of motor weakness, paralyses, atrophy or dysfunction of muscles and muscle groups, or at least disturbances in muscle tonus and changes in reflexes.

The occurrence of *cerebral symptoms*, such as insomnia, excessive dreaming, nervous excitation or depression, together with headache, vertigo, nausea and vomiting (the latter four cannot be assumed to have had cerebral origin), may be seen not to be limited to the encephalopathic type of plumbism, of which there were only two examples in the series. Whether due to the effects of lead upon the brain or to circulatory disturbances, these symptoms indicate that the central nervous system is involved frequently in lead poisoning despite the low incidence of serious cerebral intoxication. This fact is in keeping with other clinical and experimental evidence, too extensive for this discussion, that strongly supports the belief that the degree of cerebral lead intoxication is not a matter of chance variation in individual response to lead absorption, but is rather an expression of the *extent* of cerebral lead absorption. Further support for this thesis is given by the occurrence of the two cases of encephalopathy in this series, both having their origin in severe and prolonged exposure to lead dust. It is generally believed that *lead encephalopathy* in adults is the result of intense lead exposure, and that the comparative infrequency of its occurrence in present-day American industry, in comparison with an earlier period, is due to the elimination, in the main, of unregulated and grossly hazardous lead exposure. Our experience bears out this belief. The clinical evidence likewise supports it, in that when the cerebral symptoms are foremost in the clinical picture, the objective signs of increased intracranial pressure and of profound cerebral and general intoxication develop, culminating not infrequently in convulsions, coma, and death.

It is not always recognized that other serious or disabling manifestations of lead poisoning involving the nervous system

are associated only with relatively severe types of lead exposure. The instance of *bilateral wrist-drop* in this series is a case in point. Our experience indicates that tremor, hyperreflexia, varying degrees of weakness of extensor muscles in the forearm, and minor sensory disturbances are not infrequent in their occurrence among workmen under definitely hazardous conditions of lead exposure, but that full-blown neuritis and paralysis is rare and arises only from severe and usually from prolonged lead exposure. We have not seen paralyses of the lower extremities or trunk in lead poisoning in the adult, nor have we seen optic neuritis and atrophy except in association with such an obvious etiologic factor as glaucoma.

It is apparent from the foregoing data and discussion that lead poisoning as a clinical syndrome resulting from the less severe (*i.e.*, partially but incompletely controlled) types of lead exposure that characterize the American lead trades by and large at this time, is essentially a toxic derangement of the gastro-enteric tract, on which are superimposed various functional disturbances of the peripheral and central nervous system, the type and severity of which depend largely upon the severity and duration of the lead exposure. This epitome is lacking in one important respect, in that the effects of lead absorption upon the blood and the bone marrow are not included. This feature of the disease will be covered under the findings of the laboratory.

Laboratory Findings

The laboratory findings occupy an important position in diagnosis of lead poisoning in any case, and are especially valuable, as suggested previously, when the severity of the lead exposure is unknown or open to question. Indeed in many instances they constitute the only objective means for determining whether or not there has been occupational lead exposure, and for establishing its potential significance in relation to a suspected or alleged case of lead poisoning. However, if it is useful and often necessary to obtain laboratory data, it is even more important to recognize their limitations.

Characteristic laboratory findings in lead poisoning are illustrated in Table 4. A cursory examination of these data reveals a number of important facts.

1. The *erythrocyte count* is likely to yield low and perhaps quite low results, but on the other hand it may be entirely normal.

2. Likewise, the *hemoglobin content* of the blood may be significantly low, only slightly diminished, or undiminished.

3. The *leukocytes* show no characteristic change. (Although more or less specific, progressive changes in certain cell types have been reported under conditions of prolonged occupational lead exposure,[10] such changes could have but little significance when only one or a few differential leukocyte counts can be carried out in the individual case.)

TABLE 4

RANGE OF VALUES AND MEAN VALUES FOR VARIOUS ITEMS OF LABORATORY INFORMATION ON THIRTY CASES OF LEAD POISONING STUDIED BEFORE SUBSIDENCE OF AN ACUTE EPISODE

Item	Range	Mean and P. E.
Erythrocytes (M./cu.mm.)	3440–5400	4275 ± 71.0
Hemoglobin (Gm./100 cc.)	8.47–14.9	11.4 ± 0.3
Leukocytes (cu.mm.)	4300–11,000	7750 ± 300.1
Percentage polys.	35–88	60.6 ± 1.7
Percentage lymph.	12–56	32.7 ± 1.5
Stippled erythrocytes/million	720–16,000	5856 ± 688
Lead in blood (Mg./100 gm.)	0.07–0.35	0.17 ± 0.01
Lead in small sample of urine (Mg./L.)	0.07–0.85	0.23 ± 0.02
Lead in large sample of urine (Mg./L.)	0.12–0.33	0.22 ± 0.01

4. There is a significant *increase in the number of "stippled" erythrocytes* in the peripheral blood in most cases. Occasionally, the numbers are little or no greater than those found in normal healthy persons with no abnormal lead exposure. Without exception, however, stippled erythrocytes were found in the blood of these persons with active lead intoxication, and in most instances definitely abnormal numbers were found. This is in accord with our experience and that of many other workers. Indeed, except in rare instances of sudden overwhelming lead intoxication, the *absence* of stippled erythrocytes in the blood during the course of an active illness is convincing evidence that lead is not the cause of the illness.

Characteristic laboratory findings in lead poisoning are illustrated in Table 4. A cursory examination of these data reveals a number of important facts.

1. The *erythrocyte count* is likely to yield low and perhaps quite low results, but on the other hand it may be entirely normal.

2. Likewise, the *hemoglobin content* of the blood may be significantly low, only slightly diminished, or undiminished.

3. The *leukocytes* show no characteristic change. (Although more or less specific, progressive changes in certain cell types have been reported under conditions of prolonged occupational lead exposure,[10] such changes could have but little significance when only one or a few differential leukocyte counts can be carried out in the individual case.)

TABLE 4

RANGE OF VALUES AND MEAN VALUES FOR VARIOUS ITEMS OF LABORATORY INFORMATION ON THIRTY CASES OF LEAD POISONING STUDIED BEFORE SUBSIDENCE OF AN ACUTE EPISODE

Item	Range	Mean and P. E.
Erythrocytes (M./cu.mm.)	3440–5400	4275 = 71.0
Hemoglobin (Gm./100 cc.)	8.47–14.9	11.4 = 0.3
Leukocytes (cu.mm.)	4300–11,000	7750 = 300.1
Percentage polys.	35–88	60.6 = 1.7
Percentage lymph.	12–56	32.7 = 1.5
Stippled erythrocytes/million	720–16,000	5856 = 688
Lead in blood (Mg./100 gm.)	0.07–0.35	0.17 = 0.01
Lead in small sample of urine (Mg./L.)	0.07–0.85	0.23 = 0.02
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Lead in small sample of urine (Mg /L)	0 07–0 85	0 23 ± 0 02
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Considering the laboratory data as a whole, *there is nothing in them*, except some evidence of anemia, in most instances, to denote intoxication, and since anemia due to lead is not specific in its characteristics, neither this abnormality nor any other gives adequate basis for a diagnosis. On the other hand, *the analytical data provide the very significant evidence that hazardous lead exposure had occurred,* if the time interval since termination of exposure were taken into account. This, as previously indicated here and elsewhere[11] is the role of lead analyses in the diagnosis of plumbism. They perform this role admirably, but they should not be given weight in any other capacity. We have not been able to verify the conclusion of Smith and his associates[12] that a shift in the partition of lead between cells and plasma in the blood serum is indicative of lead intoxication.

Safe Occupational Lead Exposure

Experience has shown that when occupational lead exposure is *insufficient* to cause at least occasional toxic episodes resembling those described as characteristic of plumbism, no evidence is found of vague general disorders or impairment of the health of workers that differ in frequency or degree from those seen in any comparable group of unexposed industrial employees. To be sure, careful studies must be conducted over long periods of time to determine whether this is strictly true, but there is no presently available evidence which justifies serious doubt on this score. It is possible, however, that the standards now employed to define safe lead exposure may be subject to slight change, both qualitatively and quantitatively. Of the various standards that might be considered, there are two which by reason of their sound practical and theoretical background are most likely to endure.

are associated only with relatively severe types of lead exposure. The instance of *bilateral wrist-drop* in this series is a case in point. Our experience indicates that tremor, hyperreflexia, varying degrees of weakness of extensor muscles in the forearm, and minor sensory disturbances are not infrequent in their occurrence among workmen under definitely hazardous conditions of lead exposure, but that full-blown neuritis and paralysis is rare and arises only from severe and usually from prolonged lead exposure. We have not seen paralyses of the lower extremities or trunk in lead poisoning in the adult, nor have we seen optic neuritis and atrophy except in association with such an obvious etiologic factor as glaucoma.

It is apparent from the foregoing data and discussion that lead poisoning as a clinical syndrome resulting from the less severe (*i.e.*, partially but incompletely controlled) types of lead exposure that characterize the American lead trades by and large at this time, is essentially a toxic derangement of the gastro-enteric tract, on which are superimposed various functional disturbances of the peripheral and central nervous system, the type and severity of which depend largely upon the severity and duration of the lead exposure. This epitome is lacking in one important respect, in that the effects of lead absorption upon the blood and the bone marrow are not included. This feature of the disease will be covered under the findings of the laboratory.

Laboratory Findings

The laboratory findings occupy an important position in diagnosis of lead poisoning in any case, and are especially valuable, as suggested previously, when the severity of the lead exposure is unknown or open to question. *Indeed in* many instances they constitute the only objective means for determining whether or not there has been occupational lead exposure, and for establishing its potential significance in relation to a suspected or alleged case of lead poisoning. However, if it is useful and often necessary to obtain laboratory data, it is even more important to recognize their limitations.

Characteristic laboratory findings in lead poisoning are illustrated in Table 4. A cursory examination of these data reveals a number of important facts.

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Additional facts with respect to stippling of the erythrocytes may be summarized briefly. Because of wide variation in the individual response of the blood and the bone marrow to lead exposure and to a variety of other poorly defined factors, it is not possible to determine the severity of the lead exposure, or the extent of lead absorption, in the individual case, by counting these cell forms. There is a decided tendency, however, toward a prompt and progressive increase in the number of such erythrocytes, both in individuals and in groups, when the lead exposure is abruptly increased, and in the absence of proof to the contrary *such changes in the* blood should be regarded as presumptive evidence of increased lead absorption in workmen in lead trades.

Increases in stippling may not be taken as a sign of existing or impending lead intoxication, for large variations occur without symptoms or signs of illness, but they should be considered as danger signals, the urgency of which is roughly proportional to their magnitude and speed of development. The numbers of stippled erythrocytes in the blood diminish with variable rapidity on termination of lead exposure, and it is usual to find them restored to substantially normal levels long before the lead concentration in the blood and urine have shown corresponding decrease. For this reason the results in the cases included in Table 4 were considerably lower than if they had been obtained earlier.

5. The *lead content of the blood* was elevated significantly above the normal in all of these cases, despite the time interval between termination of this exposure and the analysis of the sample. No relationship could be established between the lead concentration in the blood and the severity of the toxic episode from its onset or the acuteness of symptoms at the time of the examination. The blood lead concentration may return to substantially normal levels before the urine does so, and for this reason, the urine should always be studied if the case is seen late in the course of the intoxication.

6. There is an *elevation in the lead concentration of the urine* in every instance as shown by the analysis of samples of large volume (1 liter or more). The necessity for care in the interpretation of analytical results on spot samples of urine is illustrated by the results obtained on such samples in this series of cases. One of these small samples, obviously dilute, yielded a result of 0.07 mg. per liter; while another, which was of very small volume and may have been contaminated slightly, gave the almost incredible figure of 0.85 mg. per liter. Such results would require checking if they stood alone. In these cases, however, the analyses of the blood and the large samples of urine provided all the information required

to verify the significance of the lead exposure. It is good practice, therefore, to obtain blood samples along with spot samples of urine in routine diagnostic work. If both the blood and the urine give normal or abnormal results, the interpretation is obvious, but if they are divergent, further analyses are required to establish the facts.

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Standards of Measurement of Safe Lead Exposures

1. *Expressed in terms of air analyses, the upper limit of safety for industrial lead exposure is taken to be a concentration of 1.5 mg. Pb per 10 cu. m. of air.* One interpretation of this standard holds that "when the air of workrooms regularly contains not more than 1.5 milligrams of lead per 10 cubic meters of air, as measured by standard methods, cases of disabling lead intoxication do not occur among the men who work regularly in such workrooms, and cases of questionable or mild intoxication are rare. In practice, the attempt is made to maintain the lead content of the air within such limits as will yield an average of not more than 1.5 mg. Pb per 10 cu. m. throughout the working day, while preventing the occurrence of materially higher concentrations (5 mg. per 10 cu. m. or more)."[13] Evidence of the validity of this standard has been provided by other investigators,[8, 9] and need not be enlarged upon here.

2. *The upper limit of safe lead exposure as defined on the basis of the urinary lead excretion of exposed workmen is represented by a mean value of approximately 0.10 mg. Pb per liter for samples that do not exceed 0.15 mg. per liter frequently and rarely exceed 0.20 mg. per liter.* In order that there may be no opportunity for misinterpretation of a standard which includes a range of values as well as a mean, some characteristic illustrations of results obtained on various groups of persons are given in Table 5. It should be pointed out that these data have resulted from the application of analytic methods of high sensitivity and accuracy. Less sensitive methods will yield lower values under corresponding conditions, while less accurate ones may give either higher or lower values.

The *line of demarcation* between safe and dangerous lead absorption as drawn in Table 5 is indicated by the change in the rubrics under which the data are grouped. The lead exposure that was responsible for the analytical results listed under Plant E was associated with occasional but definite cases of lead intoxication among workmen. The cases seen during a period of several years in which the severity of the lead exposure had undergone little or no apparent change, had been comparatively mild. In contrast, cases of wrist-drop had been seen among the workmen in Plant G, and one fatal case of lead encephalopathy had occurred. The analytical results grouped under all three of these plants cover a wide range and are

TABLE 5

LEAD CONCENTRATION IN THE URINE OF VARIOUS GROUPS OF PERSONS

Lead in Milligrams per Liter	Frequencies of Occurrence of Values Indicated: 24-Hr. Samples on Unexposed Experimental Subjects	Samples of Large Volume on: Unexposed Persons	Workmen in Plant A	Workmen in Plant B	Workmen in Plant C	Workmen in Plant D	Lead in Milligrams per Liter	Frequencies Samples of Large Volume on: Workmen in Plant E	Workmen in Plant F	Workmen in Plant G
0-0.019	139	42	8	3	..	3	0-0.079	11	4	6
0.02	216	51	8	110	5	11	0.08	31	27	28
0.04	17	26	3	239	6	17	0.16	14	17	20
0.06	1	3	3	104	11	10	0.24	8	7	13
0.08	1	...	2	15	5	9	0.32	2	1	3
0.10	...	...	..	...	2	6	0.40	1	2	5
0.12	...	...	..	...	1	9	0.48	1	..	3
0.14	...	...	..	...	3	1	0.56	..	2	1
0.16	...	...	..	...	..	1	0.64	..	..	2
0.20	...	...	..	...	..	1	0.72	..	..	1
0.22	...	...	..	...	..		0.80 or more	3	2	1
No. of Samples	574	125	21	471	36	71	....	73	62	86
No. of Persons	2	125	21	9	36	71	....	73	21	86
Mean	0.021	0.028	0.037	0.051	0.079	0.097	....	0.155*	0.172*	0.194*
P. E.	±0.0001	±0.002	±0.004	±0.0005	±0.004	±0.004	....	±0.007	±0.008	±0.008
S. D.	±0.009	±0.014	±0.025	±0.016	±0.010	±0.015	....	±0.087	±0.085	±0.102

* Means calculated on results above 0.18.

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0.04	17	26	1	239	6	11	0.16	14	17	20
0.06	1	3	3	101	11	17	0.24	8	7	13
0.08	1	...	2	15	5	10	0.32	2	1	3
0.10	...	...	..	...	2	9	0.40	1	2	5
0.12	...	...	..	...	4	6	0.48	1	..	4
0.14	...	...	..	...	3	9	0.56	..	2	3
0.16	...	...	..	...	..	4	0.64	..	..	2
0.20	...	...	..	...	..	1	0.72	..	..	1
0.24	...	...	..	...	..	1	0.80 or more	3	2	1
No. of Samples	571	125	21	171	36	71	....	73	62	86
No. of Persons	2	125	21	9	36	71	....	71	21	86
Mean	0.021	0.028	0.017	0.051	0.079	0.097	....	0.155*	0.172*	0.191*
P. E.	±0.0003	±0.002	±0.001	±0.0005	±0.001	±0.001	....	±0.007	±0.008	±0.008
S. D.	±0.009	±0.014	±0.025	±0.016	±0.010	±0.015	....	±0.087	±0.085	±0.102

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irregular in their frequencies in the higher levels. Irregularly occurring high values are open to the suspicion that they have resulted from the contamination of samples, and for that reason they have been ignored in calculating the means. It is also true, however, that excessively high urinary lead concentrations are more prone to occur sporadically when the lead exposure of a plant is highly variable, whether because of unavoidable technical difficulties or through disregard of hygienic measures.

The several sets of data, beginning with normal individuals from whom samples were obtained under the most favorable conditions of the laboratory, and extending through those from Plant D, are quite regular with respect to the frequencies under the different rubrics. All of the results are credible in the statistical sense, and the *range of variability* is not excessive. The range increases, however, with increase in the general level of the lead exposure. There is a distinct gap between the results on Plant D and those on Plant E. Despite this gap, the upper level of safety is set definitely at Plant D, for the reason that while no actual cases of lead poisoning have occurred in Plant D in more than 12 years, suggestive clinical evidences of incipient lead intoxication have been seen from time to time in men whose exposure has been increased for short periods by reason of changes or difficulties in plant operations. The workmen in Plant C showed no evidences of lead absorption other than the elevation of the lead content of their excreta (and also of their blood, which had a mean level of 0.05 mg./gm.). Those in Plant B showed only a slight elevation of the urinary lead concentration. There was no statistically significant increase in their blood lead concentration over that of persons with no occupational lead exposure. No statistically valid increase could be detected in the numbers of stippled erythrocytes over normal levels among the men in Plants, A, B, and C, but a well defined increase could be demonstrated in the men in Plant D. (The relative insensitivity of analytical and microscopic changes in the blood in detecting lead exposure can be recognized from the two foregoing statements.)

There is reason to believe that the critical level of safe lead exposure set on the basis of urinary lead excretion does not coincide exactly with that expressed in terms of air analyses, and that it is somewhat on the safe side. Examination of the recent data of Dreessen and co-workers of the U. S. Public Health Service[9] would seem to indicate that exposure to atmospheres containing less than 1.5 mg. Pb per 10 cu. m. may yield urinary values that average higher than 0.10 mg. per liter. Their data, while perhaps not comparable to those given above on a strictly quantitative basis, are, nevertheless, in general agreement with what has been said on the subject of the urinary lead excretions in relation to lead exposure, in the foregoing discussion. Time and further work will be required to work out an exact correlation between the two standards.

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THE TOXIC PROPERTIES OF SELECTED LESS FAMILIAR METALS

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and
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FOR metals there are at least as many definitions as there are scientific groups concerned with them, as the metallurgist, the geologist, the chemist and the physicist. The workers in any one of these groups, while adhering to special metal characteristics related to their special fields, recognize the validity of other definitions elsewhere applied. While the electrophysicist may stress electrical conductivity in relation to metals, he will concede that the chief concern of the chemist in his acceptance of minerals as metals may center about the type of compounds produced or their capacity to liberate hydrogen from water. This community of overlapping interests necessarily leads, in addition to multiple definitions, to multiple classifications, some of which are archaic. Thus metals may be grouped as noble, useful, precious, heavy, light, lesser, alkaline earth, and so on. Some minerals widely accepted as metals are placed by chemists in the category of metalloids because of their ability to produce both acid and alkali compounds. Here fall, among others, tin, antimony, zinc and manganese. The interests of the toxicologist are intertwined with no one of the special worker groups just mentioned, but with all. Thus fealty to no one highly technical definition is required. Instead, the layman's definition of metals as substances commonly having brightness, ductility, malleability and fusibility may be invoked.

ALLOYS

Concisely writing, there is no such thing as a pure metal unless some of the products of the cyclotron may be so

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classed. Thus, theoretically all metals are alloys. More practically, alloys may be regarded as intentional mixtures of a base metal with other metals called additives. Natural or fortuitous metal mixtures with some predominant base are universal. While elemental metals, as noted above, are comparatively few, the number of alloys is legion. Already more than 8200 have been described. A typical alloy, here named purely as an example, may be found in stainless steel of recent fame. While there are many stainless steels, a representative one, on a qualitative basis only, contains iron as the base metal, chromium as the essential additive, with some or all of the following: carbon, nickel, silicon, aluminum, tungsten, titanium and molybdenum. The numerous possible combinations within this group are apparent.

For toxicologists and physicians in general, these alloys through sheer numbers are of greater significance than the elemental metals. A known toxic element such as lead is a frank, undisguised, medical enemy. Let this same lead be present in the alloy of a journal metal or leaded steel and you have a toxicologic saboteur. In the founding of zinc, without any accidental overheating of the metal, the prospects of metal fume fever are actual but moderate. Contrariwise when zinc is alloyed with copper to produce brass, the high melting point of the copper in contrast to that of zinc greatly facilitates the volatilization of the latter and promotes the prospects of zinc fever. An array of further instances might be adduced linking alloys to toxicology as a prolific source of possible worker involvements under circumstances not always obvious.

METAL COMPOUNDS

Elemental metals, frequently associated with injurious properties, by no means are necessarily dangerous as such. If silicon be rated as a metal—and this paper is no staunch supporter of such contention—it may be staged as an example of an element for which no or scant harmful properties are recognized.* However, its compound silica (SiO_2) has

* McCord, C. P., Frederick, W. G. and Stolz, S.: The Toxicity of Silicon. J. Lab. and Clin. Med., *23:* 278 (Dec.) 1937.

furnished during the past decade the outstanding adventure in trade diseases. Entering into organic compounds, silicon may find itself to be a part of methyl silicate, for example—a substance of known toxicity and standing apart as dissimilar to silica—yet silicon *per se* has yet to be culpated.

Claims have been made that elemental zinc is nontoxic. While this may be true, yet it may be granted that zinc chloride as used in the wood preserving industry may constitute a skin irritant; zinc sulfate as a precursor of lithopone may act as a corrosive agent and recently formed zinc oxide is the well known source of zinc chills.

Aluminum as such, however dangerous as a combustible under some circumstances, is not toxic in pure form, but there are compounds of aluminum that may act on human beings injuriously. The term "aluminosis" largely is a name.

In the complex and almost endless variety of compounds of metals numerous factors influence toxicity, setting some compounds of a metal apart as nontoxic while others from the same metal obviously are otherwise. In the case of chromium, a shining example, *valence* may be the determining factor. With a valence of 6, its compounds, chiefly the chromates, are well known harmful substances. When the valence is 3, toxicity is scarcely known or expectable. Chromium's valence of 2 leads only to compounds that are unstable so that the toxicity of such is somewhat conjectural.

The *physical properties* of metallic compounds at times influence practical situations. The mineral tripoli is cryptocrystalline silica. Its content of free silica may exceed 99 per cent, but cases of silicosis from tripoli dust are rare in spite of possible dusty exposures, due to the electrostatic properties of this material which lead to agglomeration of small dust particles into larger masses with rapid dropping to floor level because of mass.

Solubility of metallic compounds likewise may determine the extent of toxic properties. Barium sulfate, used freely in x-ray work, represents a compound of no danger, but some other barium salts are distinctly injurious under fit circumstances. Insolubility determines the safety of barium sulfate. When the dusts of lead compounds are inhaled, solubility

ultimately may play no important role, but it may be granted that such insoluble compounds as lead silicate and lead titanate provide less possibility of lead poisoning than other lead compounds such as the carbonate or oxide. On the other hand, by the ingestion route, lead silicate may be regarded as almost innocuous on comparison with the readily soluble lead acetate. It is the objective of this brief section to contend that there may be varied circumstances under which some metals or their compounds may not be regarded as poisonous or otherwise injurious.

TOXIC METALS

On a somewhat academic basis, it may be granted that any and all metals directly or through their compounds possess some injurious properties for those harboring them or in contact with them. It is a futile enterprise to claim, as has been done in some courtrooms, that because a metallic salt regularly may be found in body fluids, tissues or excreta this constitutes proof of the total harmlessness of such a metal. Lead compounds regularly may be found in the urine, but this fact does not provide any proof that more lead may not produce a direful affection. Traces of manganese may be essential in physiologic economy, but this dependency gives no whit of assurance that manganese poisoning may not be produced after suitable exposure to manganese dioxide. Iron is one of the least of poisons and yet from iron may be produced compounds in which the iron ion itself may play some role in the disturbances produced. Some metals and/or their compounds are believed to possess extraordinarily toxic features and yet are of no great import because of little use—uranium has been tagged as the most toxic metal known to earth and yet the scantiness of its use has attracted little attention to it. In 1936 the total import of uranium in any form was only 170 tons. Its use apart from the laboratory extends to the ceramic, photographic, dye-making and paint-coating industries. The chief compound is sodium uranate. Yet the cumulative index volume of the Journal of Industrial Hygiene and Toxicology lists not one item indicating actual poisoning from this most toxic of all metals.

It is dangerous to conceive of minor metals as substances apart from useful metals. At the present time, there is no such thing as a useless metal, if it may be provided in commercial quantities. The highly rare alabamine, the last of the ninety-two elements to be discovered, is a useless metal only because it is so rare as to exist not even as a laboratory curiosity. Even so little known a metal as cesium, one of two liquid elemental metals, mercury being the obvious other, is so important that without it there would this day be no talking motion pictures. Despite this disposition to do away with the term "useful metals" it is woefully tragic that inadequate information has been furnished about many minor metals. Where are the toxicologic publications about scandium, or palonium, or masurium? They may exist, but they do not constitute a plethora.

Between the traditionally important industrial metals such as iron, copper, lead and zinc on the one hand, and the traditionally minor metals such as boron, indium, vanadium, and so on there are several, known but not well known to the medical profession, that surely have worn out, through their indispensable services to industry, any claim that they are useless or minor metals. More than ever present-day martial requirements have brought into prominence a dozen or more metals long known to possess toxic properties, but never accorded a seat on the front row of practical dangerous work materials. Out of a much longer list, six such metals have been chosen as items for detailed discussion, the details being limited chiefly by available material. In nearly all instances these metals are utilized as alloys or in the form of their compounds. The lesser metals, chosen somewhat at random, are: Chromium, Magnesium, Cadmium, Manganese, Antimony and Barium.

CHROMIUM

The choice of chromium as a selected metal in this series of currently outstanding metal alloys and metallic derivatives is based almost entirely on the desire to emphasize the little known fact that neither metallic chromium nor the greater number of its derivatives constitute *dangerous* work materials. Instead toxicity is associated only with a small group of

derivatives, chiefly chromic acid, certain chromates and dichromates, ordinarily bearing a valence of 6.

Sources and Uses

At least by 1938 governmental military agencies had marked chromium as one of four mineral commodities indispensable to national defense and calling for placement in the first class of priority restrictions. This necessity is first of all related to the use of chromium in the preparation of stainless steel, which operation accounts for 75 per cent of domestic consumption. Chromite or ferrous chromite ($Fe(CrO_2)$), the dominant ore form of chromium is found in Turkey, several portions of Africa, including Rhodesia, and also Cuba, Russia, England, New Caledonia, with minor production in this country in California, Pennsylvania, and New Jersey. The military significance of this metal is reflected in the fact that continuous German threats against Turkey are believed to have rested more upon the vital need for the chromium of that country than any other economic aspect. Although military necessity has led to frantic efforts to increase the production of chromite everywhere, the results of such measures are not fully disclosed. The yearly worldwide production will soon be near 1,000,000 long tons of chromite, and Africa probably will continue to provide some 50 per cent of the world's production. The extent of domestic chromite production is reflected in the fact that in the "Minerals Yearbook for 1939" mention is made of 810 long tons from domestic sources against 352,085 long tons imported. Chromium apart from the steel industry utilization has many applications such as in electroplating, pigment manufacture, tanning, rustproofing of metal and in refractories. A long list of highly varied industrial activities requires small quantities of chromium, including applications in lithography, blueprint production, oil bleaching, artificial flowers, explosives, wallpaper, linoleum, and matches.

Properties

This hard, steel-gray, lustrous substance has an atomic weight of 52.01, valences of 2, 3 and 6, although metallic

chromium is not in a valence state; a specific gravity of 7.1, melting point of 1615° C. and a boiling point of 2200° C. It is soluble in some dilute mineral acids, not including nitric acid, and is readily attacked by caustic alkalis and alkali carbonate, which fact hampers its full usefulness after plating, such as on exposed automobile parts. Metallic chromium is prepared by reduction of its chief ore, above mentioned as chromite, the chromic oxide being produced by the heating of chromite with an alkali. Chromic acid chiefly is prepared for commercial purposes through the treating of barium or lead chromates with a mineral acid. A long list of chromium compounds exists, such as chromium carbonate, chloride, nitrate, sulfate, and so on, and at the same time zinc, lead, potassium, and ammonium chromates or bichromates. This distinction between chromium compounds and the derivatives of chromic acid, together with other discussions as to the classes of compounds formed from chromium are clearly presented by Akatsuka and Fairhall.[1]

Nature of Toxicity

At once a sharp distinction should be made between the *chromic salts* which are almost entirely harmless and the *derivatives of chromic acid*, which contrariwise are injurious. In essence this means that when the valence of chromium is 3 in any of its derivatives, significant toxic properties are not expectable. On the other hand, in its compounds in which the valence is 6. toxicity may be definite, although there is some lack of uniformity and severity. Metallic chromium is nontoxic and unlike lead or zinc does not lend itself to the unintentional formation of harmful compounds. The fact that the toxicity of chromium derivatives so clearly varies is of great significance to the physician in medicolegal work. In any situation predicated upon damage from chromium derivatives, the defense is afforded enormous advantage if it may be shown that the alleged offending material is of the trivalent variety and therefore inert. Ordinarily this disclosure comes as a surprise to plaintiff attorneys and medical witnesses alike. Only rarely is it laudable for any physician to support an alleged claim of injury attributed to chromic salts. It

naturally follows that any industrial use of chromium derivatives if there be any choice should select chromic salts in contrast to the derivatives of chromic acid.

The action of harmful derivatives of chromium is essentially local, being confined to the *skin*, *conjunctivae*, *nasal tissues*, and the *bronchial tree*. Apparently the possibility exists that allergic states may be induced by chromium derivatives as described by Smith.[2] While broken skin or previously damaged mucous membranes may greatly facilitate the action of chromium derivatives, it is by no means essential that the skin be broken in order that a chrome dermatitis may arise.[5] Even though a pronounced chromium bronchitis arise, primary action probably always is on a local basis. Possible subsequent pneumonia may constitute a complication. At various times the claim has been made that pulmonary carcinoma may follow the prolonged inhalation of chromium dust, vapors, or mists. If this be true, it is not yet sufficiently established to justify a cause and effect relationship. The three commoner varieties of localized chromium derivative action deserve discussion.

1. *"Chrome Hole," "Chrome Dermatitis," "Chrome Ulceration of the Skin."*—These lesions may arise at any point on the skin, but ordinarily occur about the hands, notably the fingers, and the feet. In the absence of previously broken skin, any damage may constitute a diffuse dermatitis, painful in character and prolonged in duration. In case of broken skin, isolated ulcers are expectable. Such skin ulcers may follow skin contact with solutions, the settling of dusts or the unknown deposition of a sizable particle of such materials as the chromic anhydride or some chromate. This latter becomes quite possible in connection with the anhydride, which has limited explosive properties and which fairly often detonates at the time of the careless opening of a container. Particles of the anhydride may be deposited on the clothing or skin, with menacing results.

The character of the diffuse dermatitis is scarcely typical except for pain out of proportion to the apparent severity. On the other hand, chrome ulcers are fairly characteristic. These ulcers are usually round except when they occur im-

mediately at the nail borders, are indurated, whitish, undermined, sometimes painless. The center represents an eschar and the ulcer is usually larger than indicated by its surface area, that is, it is jug shaped with some disposition for the jug mouth to heal over. The action of the offending chromium is persistent over a period of weeks, illy responding to efforts of hydrolysis and unyielding to the usual neutralizing agents of therapy. Any number of ulcers may exist, all being of different sizes, at times of different stages, usually without any evidence of secondary infection. Although some ulcers may be edematous, leading to a heaped up appearance of the undermined ulcer, others may be free of edema with the surface depressed into the ulcer crater.

2. *Upper Respiratory Tract Involvement.*—Just as the traditional "chrome hole" of the skin may overshadow diffuse dermatitis, so the traditional nasal perforation may minimize the fact that the inflammation from chrome dust or mist may not be limited to the well known vulnerable spot on the septum, but instead may be somewhat general, may be localized elsewhere, or may resemble infectious rhinitis since, unlike the skin lesions, nasal inflammation from chromium derivatives may be accompanied by purulent processes. Actual *perforation of the septum* may be regarded as a common end-stage. The point of election is about ¼ inch from the lower and anterior margin of the septum; the ulceration extends in a direction upward and backward. This point is precisely that where inhaled dust alights.[8]

3. *Bronchitis.*—It would appear expectable that inhalation of toxic derivatives of chromium in the form of dusts or mists might be accompanied by inflammatory reactions in the lower respiratory tree. Theoretically it is improbable that all such effete materials might be arrested in the upper respiratory areas. Actually, significant chemical bronchitis is rare and by some denied. Asthma has been described, but the bronchitis is more often regarded as existing on an infectious basis, secondary to involvement of the upper tract. Any respiratory tract involvement is commonly nondisabling and few claims for compensation even when large perforations have occurred arise since customarily compensation is paid not because of the existence of a disease but solely on account of disability.

Prevention and Treatment

Quasi-official standards related to the inhalation of chromium usually specify a maximum allowable concentration of chromium as chromate or dichromate dust or as chromic acid mist of *1 mg. of the chromic trioxide* (CrO_3) *in 10 cubic meters of air.* In the case of solutions, 1 per cent of some dichromates are known to produce dermatitis on unbroken skin. Since industrial requirements may not permit the use of weaker concentrations, it follows that work exposures to dilute solutions may require glove protection, goggles and similar articles.

For the determination of chromium derivatives in the air, it is possible to collect suitable samples with the *impinger apparatus*, the fluid medium of which should contain sodium hydroxide. Following this step, *quantitative determinations* may be made through the addition of potassium iodide to a known portion of the collected alkaline solution, followed by acidulation with hydrochloric acid and titration with 0.01 N sodium thiosulfate.

Manifestly, harmless chromium derivatives should be substituted for harmful ones where possible. Personal protective garments as earlier mentioned are often requisite. The application of emollients to the skin and nares surfaces affords some protection. Suitable exhaust systems provide the best type of control.

By way of *treatment* it has been found that ordinary neutralizing medicaments are often useless. Hydrolysis is not brought about and the retained eschar may act as a foreign body. Reed and McCord found that applications of weak solutions (5 per cent) of such skin wetting materials as citric or tartaric acid or their combination were effective in arresting the long continued action of chromium derivatives, after the removal of eschars. While these statements apply more especially to chrome holes of the skin, yet conceivably, sprays of the same material might prove advantageous in nasal involvements.

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MAGNESIUM

Magnesium is chosen for the list of metals of newly increased importance not so much because of the peculiar skin damage sometimes produced but as to make physicians further aware of the possibilities of *fire burns* in the magnesium industry and the likelihood of *accidents* or *occupational diseases* from a group of highly dangerous chemicals used in the finishing of metallic magnesium.

Sources and Uses

Magnesium along with aluminum constitutes the chief member of the light metals. Military exigencies, particularly related to aircraft, have made magnesium a truly precious metal although "precious" obviously is here used in an unusual sense. Little warrant exists for any comment on the quantity of magnesium now being produced or even its sources. Any published figures are outmoded. In 1938 the world output probably did not exceed 22,000 tons, but during that year there was developed the Dow method for the protection of magnesium alloys against corrosion. Other forms of corrosion prevention necessitate the use of various toxic materials including hydrofluoric acid, sodium dichromate, and arsenous oxide. Thus whatever toxicity inherently resides in magnesium and its compounds is complicated by the ancillary use under some circumstances of much more dangerous substances.

Magnesite ore (magnesium carbonate ($MgCO_3$)) is found in Austria, Greece, France, Germany, Canada, Japan, Nor-

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Selected References

1. Akatsuka, K. and Fairhall, L. T.: The Toxicology of Chromium. J. Indus. Hyg., *16:* 1 (Jan.) 1934.

"In the first, a visible particle of metal is found. If the injury be not treated, there ensues, in two-three days, a rapid and progressive inflammation of the site and of the lymphatic system. Vacuole formation occurs in the tissues as a result of hydrogen formation consequent upon chemical reaction between the metal and the fluids in the tissues.

"In the second type of injury, the causative agent is metal dust which enters a wound resulting probably from some other accident. The wound heals rapidly, but a painful granulomatous infiltration, which may persist for months, occurs. Subsequently, these suddenly develop acute symptoms of inflammation, as in the first type of injury. Vacuole formation, however, does not occur. Instead, granulomatous cells and eosinophiles, together, at times, with giant cells, are found."

Since in aircraft metals, magnesium may be alloyed with others, it is not precisely established that these troublesome affections represent solely a magnesium action. In fact the implication elsewhere in the same paper is that other metals may contribute. It is noteworthy that bacterial agar cultures were made in which dust or spicules of heavy metals were present, leading to a bacteriostatic action, but no such results occurred from similar applications of particles of the light metals. However, it is to be recognized that magnesium is not a toxic metal in the sense that arsenic or mercury is toxic.

Prevention and Treatment

The real problem connected with metallic magnesium is to be found in the realm of safety and fire control. Numerous explosions and fires have led to highly specialized programs for work protection including special fire-extinguishing powders, snap-on garments, and so on. Metal fume fever from magnesium may both be prevented and treated through those well known measures associated with zinc chills. The chief new medical element is that of magnesium dermatitis which obviously can be prevented through personal protection. It is noteworthy that spicules of *asbestos*, a complex magnesium silicate, are credited with producing more than expectable damage on penetrating the skin.

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9. Injuries Caused by Light Metals. Light Metals, 4: 105 (May) 1941.
10. Whitburn, L.: Fire Hazards when Machining Magnesium and Its Alloys. Light Metals, 4: 75 (April) 1941.
11. Berger, H.: Bases of Safety in Light and Ultra-Light Alloy Manipulation. Light Metals, 4: 44 (March) 1941.

way and in this country in California, Nevada and Washington, among other places. Much magnesium has been procured through the electrolysis of inland brines and at this time factories are producing considerable amounts of magnesium from seawater. Military demands for metallic magnesium so cloud the normal and potential industrial uses of this metal and its compounds that nondefense applications are almost nonexistent. For the metal alone, there is a normal use in furniture manufacture, musical instruments, machine parts, optical mirrors, flashlight bulbs, pyrotechnics, and others. The *compounds of magnesium* both organic and inorganic have wide application in the arts, in medicine, and in industry. While magnesium sulfate or Epsom salts may by many be only associated with the toilet room, a great deal more in the aggregate may be applied in industry's technologies, including the weighting of cotton and silk, in tanning, in bleaches, in paper manufacture, in fireproofing fabrics in the textile industry, in fertilizers, explosives and matches. The recently attained high estate for metallic magnesium is reflected in the appearance some four years ago of a journal entitled "Light Metals."

Properties

Magnesium has an atomic weight of 24.3, a valence of 2, and was first produced by Davey in 1808. Magnesium is lustrous, malleable, and hard. In the form of fine dust it is highly explosive and inflammable. In moist air it is discolored. The specific gravity of this lightest of metals is 1.74. It melts at 651° C., boils at 1110° C. and is soluble in dilute acids.

Nature of Toxicity

To the physician and the industrial hygienist, magnesium in the form of its silicate (asbestos) long has been associated with the *pneumoconioses*. Recently produced magnesium oxide is a common source of *metal fume fever*. Now it develops that spicules of metallic magnesium penetrating the skin lead to a severity and duration of injury well out of proportion to foreign body trauma. Out of 5000 examinations of such injuries, occurring in Germany, *two* types have been described:[9]

Properties

The following list of properties of cadmium are cited from a recently approved standard of the American Standards Association (Nov. 2, 1941).

Cadmium is a silvery white metal with a slight bluish tinge and is much more ductile and malleable than zinc. It has an atomic weight of 112.41, a melting point of 320.9° C., a boiling point of 767° C., density 8.6 g. per cm.^{3} at 20° C., solubility of cadmium (OH) in water at 25° C. 1.73 x 10^{-4} g. anhydrous/100 g. solution.

Nature of Toxicity

Under industrial conditions, cadmium and some of its compounds are toxic when absorbed either through the lungs or rarely the gastro-intestinal tract. *Entry by mouth* leads to vomiting, salivation, loss of appetite, loss of weight, diarrhea, nausea, vomiting, rapid pulse, discolored urine, nephritis, fatty degeneration of the liver. The *inhalation* of cadmium fume may induce a lobar or bronchopneumonia, which may be associated with edema and atelectasis. Under some conditions, inhalation may lead to some of the manifestations associated with ingestion. In addition, cadmium may lead to *metal fume fever.*

It may be noted at this time that the A.S.A. standard just created is 1 mg. of cadmium per 10 cubic meters of air. By comparison the quantities that may be ingested with food as cited below become enormous. *Chronic poisoning* in industry has been described as manifest by digestive and nutritional disturbances and cachexia. While ingested cadmium usually leads to explosive outbreaks, it is conceivable that low grade chronic poisoning might arise.

Cadmium Food Poisoning.—In this instance, it is desirable to include an abridged presentation of food poisoning by cadmium. Of several outbreaks, those described by Frant and Kleeman[15] are the source of much of the following:

Five outbreaks are mentioned and four are described, in which at least fifty persons were involved. The chief *symptoms* described are nausea, vomiting, diarrhea, abdominal pain or discomfort, and general weakness. In the first instance,

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15. Minerals Yearbook, 1939, p. 710. U. S. Dept. of the Interior, Bureau of Mines, Washington, D. C.
15*a*. McCord, C. P. and others: Chemical Gas Gangrene from Metallic Magnesium. Indus. Med., *11:* 71 (Feb.) 1942.
15*b*. Meek, S. F. and others: The Physiologic Action of Metallic Magnesium. J. Indus. Hyg. (June) 1942.

CADMIUM

Since January, 1941, not less than 315 cases of food poisoning clearly have been caused by cadmium in contrast to a total of twenty cases earlier reported in the literature. This situation is in part related to extended uses of cadmium for *plating* purposes incident to national emergencies.

Sources and Uses

In the United States, the ratio of cadmium production versus cadmium imports is on the order of six to one, thus indicating an extensive domestic supply. At least thirteen states can produce cadmium or cadmium compounds under emergency conditions. In 1939 the import duty on cadmium was cut in half, thus creating a situation unfavorable to domestic production during that year. The uses of cadmium are such as to cause wide fluctuation during some years, 1938 being one of the worst years in cadmium history in the United States in contrast to immediately preceding years. Total domestic consumption during any good year approximates 5,000,000 pounds. The chief sources of import into this country are Canada and Mexico. This metal is obtained chiefly as a by-product from zinc ores, and in the purification of zinc the hazard of cadmium poisoning may be introduced. The chief uses of cadmium are in the production of bearing metals, chiefly for gasoline engines, for plating purposes, in the manufacture of paints, and in alloys other than bearing alloys.

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17. Jacobs, M. B.: The Chemical Analysis of Food and Food Products. D. Van Nostrand Company, Inc., New York, 1938, p. 141.
18. Prodan, L.: Cadmium Poisoning: II. Experimental Cadmium Poisoning. J. Indus. Hyg., *14:* 174, 1932.
19. Fairhall, L. T. and Prodan, L.: The Colorimetric Determination of Minute Amounts of Cadmium. J. Amer. Chem. Soc., *53:* 1321, 1931.
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MANGANESE

This metal with its compounds is representative of a strategic material in the United States, the supply of which is largely dependent upon import. A second reason for its appearance in this category results from the fact that manganese poisoning is one of a limited number of occupational diseases *that may lead to hopeless total disability from involvement of* the central nervous system.

Sources and Uses

The domestic production of manganese ore until the emergency period approximated 25,000 tons per year against some 500,000 tons from import sources. However, banks of stores have led to extensive accumulations. At least sixteen states are capable of producing some manganese. Manganese and its compounds find chief use in alloys, in dry storage batteries, in the glass industry, in pharmaceuticals, in dyes and paint manufacture, but the number of classes of workers exposed is high, including more than forty occupations, some of which may seem remote, such as linoleum makers, pottery workers, and bleachers.

Properties

Manganese in its pure state is a soft, reddish-gray metal with an atomic weight of 54.93, a density of 7.2 g. per cm.^{3} at 20° C., a melting point of 1260° C., a boiling point of 1900° C., and a vapor pressure, extrapolated below freezing point, of 1 mm. Hg at 1227° C.

lemonade which had been chilled in ice cube trays of an electric refrigerator was the source. In the second outbreak, home made punch, similarly produced, was the cause. In the third, a raspberry gelatin chilled dessert; in the fourth the drinking of iced tea was responsible, cadmium being present in a metal pitcher in which the iced tea was cooled, there having been added lemon juice—an acid action seems to be essential. In the first instance, 0.3 mg. of cadmium was present per gram of liquid; in the second 0.067 mg. per gram; in the third 0.53 mg.; in the fourth 0.16 mg. Frozen ices on sticks have been found to contain 0.015 mg. per gram. In the iced tea episode, it would appear that a single 8-ounce glass would contain approximately 35 mg. of cadmium. While exact data are lacking, the inference is that *minute quantities* of ingested cadmium may produce distressing manifestations. It is possible that some of the numerous food poisonings attributed to salmonella or other organisms or bacterial toxins may have in fact been caused by cadmium contaminated foods and ordinarily from cadmium plated food utensils. Cadmium is little soluble in water but appreciably soluble in weak acids such as from fruit juices.

The determination of cadmium in food or vomitus is described by Jacobs.[17]

Prevention and Treatment

Manifestly cadmium plating of any kitchen utensil is undesirable. Cadmium foils for the wrapping of food have been contemplated but obviously would be undesirable in the presence of acids. Under camp or picnic conditions, where ofttimes metal washtubs or G. I. cans may be impressed for culinary purposes, the possibilities of cadmium poisoning should be recognized. In industry prevention largely centers about the adequate entrainment of cadmium dust and fume at the point of origin, always maintaining atmospheric conditions below the level of the standard above mentioned. Cadmium taken into the body may be retained in the liver and kidneys along with bony tissues. Excretion is through the kidneys and gastro-intestinal tract. There is no known specific treatment, but indications for symptomatic therapy are clear and the protection of the liver and kidneys is indicated.

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BARIUM

Selection of this metal for this present discussion is prompted by the safe application of its compounds under so many conditions that in turn may engender the belief that barium always is nontoxic. A barium compound is a prime component of lithopone which, as a white pigment, is a praiseworthy substitute for lead. This use of barium provides no exposure but other situations should create respect for toxic properties.

Sources and Uses

Crude Barite ($BaSO_4$) is the raw material used in the preparation of most barium products. Some idea as to the extent of national use derives from the fact that about 340,000 tons of crude barite are produced yearly. Missouri, Georgia, California, Nevada, Tennessee, Texas and Virginia are producing states, Missouri leading. Many other states make use of barite through direct application or in the manufacture of barium products. Lithopone and *blanc fixe* are the chief industrial products from barium. Lithopone represents a combination of barium sulfate and zinc sulfide, which, however, are derived from solutions of barium sulfide and zinc sulfate. Other uses of barite or barium compounds include well drilling, glass manufacture, rubber production, cosmetic products, heat treatment of metals, x-ray diagnoses, fireworks, tanning, photography.

Properties

The properties of metallic barium which in themselves are little related to toxicity consist of an atomic weight of 137.36, a specific gravity of 3.5, a melting point of 850° C., and a boiling point of 1140° C. As a metal it is yellowish white, with low luster and is so readily oxidizable that it must be kept under cover of some hydrocarbon or other air ex-

Nature of Toxicity

By oral intake manganese and its compounds are comparatively nontoxic when ingested in small doses, for which reason this comment is limited to the *inhalation* portal. At this time no well accepted standard exists, but by common consent it is recognized that some *50 mg.* of manganese daily inhaled represents the maximum tolerable limit. Greater amounts taken into the lungs may lead to a variety of *signs and symptoms.* In industry, the disease is always chronic and an exposure of at least two months appears to be requisite. Among other symptoms are characteristic gait, propulsion and retropulsion, tremors, masklike facies, impulsive laughter, speech disturbances, exaggerated reflexes, pains in extremities and back, and micrographia. All considered, McNally has listed eighty-one signs or symptoms. *Laboratory evidences* are of limited value since urine is commonly negative for manganese although the blood normally may show such traces as 0.01 mg. per hundred grams of blood. A moderate polycythemia may occur along with a lymphocytosis. Since manganese is a constant constituent of biologic tissue, microchemical determinations on a qualitative basis are of dubious value. The chief involvement may be in the pyramidal system or in the striate body. Degeneration of the lenticular nucleus and nearby areas may occur. Manganese poisoning usually is progressive leading to disabling paralyses with permanent invalidism, but without prospect of shortened life. Customarily death is due to intercurrent causes.

Prevention and Treatment

Numerous therapeutic measures both mechanical, thermal and chemical have been applied with futile results. At the present time, *no treatment* promises any hope of recovery. Prevention is readily procured in industry through the entrainment of dusts by exhaust systems or through the wearing of personal protective devices. In the literature cited below details are furnished as to the methods of manganese determination in the air.

agents such as arsenic or lead. Its manifestations in part resemble those of both arsenic and lead. This very fact of its uncertain status in industrial toxicity accounts for selection here.

Sources and Uses

Antimony was one of ten minerals classified as strategic in national defense long before the recognition of an emergency. This country is dependent in large measure on antimony imports. Until recently China was the source of as much as 70 per cent of this country's antimony. In recent years 85 per cent of this metal has been obtained from Central and South America. At no time has domestic production exceeded 5000 tons, at least up to 1939. The yearly consumption under normal conditions averages about 10,000 tons per year. This substance finds extensive use in type metal although there is some prospect that plastics may invade this field. Antimonial lead is well known to battery manufacturers in the production of grids for parts. Some bearing metals contain antimony. In the manufacture of colors and paints various antimony compounds find application. Enamel ware represents another outlet for this chemical. Many lesser uses are known, such as in fireworks, rubber production, munitions, alloys, pharmaceuticals, and so on.

Properties

The metal antimony has an atomic weight of 121.76, a specific gravity of 6.68, a melting point of 631° C., and a boiling point of 1380° C. Antimony is rarely more than 99 per cent pure, as a metal is silver-white, lustrous, hard, brittle, or from crumbling may exist as a non-tarnishing lustrous powder. It little dissolves in cold acids or water, but may dissolve in hot concentrated hydrochloric acid. It is best known to medicine as a constituent of tartar emetic.

Nature of Toxicity

Like many other metals antimony *per se* may be nontoxic. Any reference to the general toxicity of this metal must be guardedly made, because of the undeniable confusion that has grown up around it. On the one hand, organic anti-

cluding substance. At least eighty inorganic and organic compounds of barium are known and the number that might be produced is much larger.

Nature of Toxicity

All water- or acid-soluble barium compounds are toxic. Most instances of serious poisoning by this metal have followed *oral ingestion* which means that industrial poisoning is rare. In industry, injurious results chiefly arise from dermatitis, loss of hair or graying of hair. Taken internally soluble barium compounds may lead to vomiting, diarrhea, severe abdominal pain, lowered temperature, impaired speech, difficult swallowing. Two hundred milligrams constitute a toxic dose. The use of magnesium or sodium sulfate as an antidote may be effective. In some industries, gross quantities of barium compound dusts are prevalent. Ofttimes these compounds are insoluble and the claim repeatedly is made that no hazard is involved. Since inhaled dust remains in the lung, and eventually must be dissolved, justification for this attitude may not be warranted. It is believable that industrial barium poisoning now regarded as rare may be more common than recorded.

Prevention and Treatment

Since systemic poisoning from barium compounds in industry is practically unknown, no well devised method of treatment exists. The ready prospect of skin or mucous membrane irritation, or depilation, may necessitate the coating of exposed portions of the skin with protective ointments or the wearing of protective garments. The entrainment of dusts at the point of origin affords protection.

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ANTIMONY

Industrial antimony scarcely possesses an entity as a toxic agent since nearly always it is associated with other toxic

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RECENT PROGRESS IN AVIATION MEDICINE

BENJAMIN F. JONES, M.D.*

Aviation medicine as a medical specialty originated during the period just before the war of 1914–1918, and developed during the war under the demands of military flying.[1] As a branch of industrial medicine it was of negligible importance until the great increase in commercial and military aviation brought it into prominence during recent times. The events of the last three years have enormously stimulated laboratory and clinical research and public interest in aviation medicine. To meet the demands of expanding air forces for flight surgeons, physicians and medical students are receiving accelerated training in aviation medicine. In many ways the medical activities of the war effort are focussed on the field of aviation medicine. The majority of this work cannot be published currently in detail since its disclosure may yield advantage to the enemy. Nevertheless it is possible to indicate the recent developments in some of the more important problems of aviation medicine, especially in those fields which are of interest to the industrial physician.

Literature.—The general principles of aviation medicine are well presented in recent publications of Armstrong,[1] Ruff and Strughold,[2] and the War Department.[3a, 3b] A number of noteworthy reviews dealing with special topics and current trends have appeared.[4, 5, 6, 7, 8, 9, 10, 11]

Among the most valuable recent publications in aviation medicine are two handbooks for the guidance of fliers and those whose task it is to keep them physically fit. The earlier of these is the Medizinischer Leitfaden fur fliegende Besatzungen, by von Diringshofen,[12a] an English translation of which is now available.[12b]

* Passed Assistant Surgeon, Division of Industrial Hygiene, National Institute of Health, U. S. Public Health Service, Bethesda, Md.

monials are highly valuable therapeutically in the treatment of the trypanosomiases. Conversely, tartar emetic is the well known Micky Finn of dive repute. Antimony was concerned in the famous Mabrick poisoning case in England where an American woman was imprisoned for fifteen years on the allegation of poisoning her husband, a murder, if a murder, that was never fully solved. Regardless of much admitted confusion, experimental work with known antimonial compounds has shown that locally antimony produces a *dermatitis* of small pustular nature, resembling smallpox and not unlike the so-called "arsenic pox." *Local action* may be present about the mucous membranes of the nose, the mouth, throat, lips and these may be accompanied by salivation. In acute poisoning, *vomiting* is a common feature, and drowsiness, weakness and convulsions occur. If recovery takes place, a loss of hair may arise. The *chronic form* may be marked by insomnia, vertigo, headaches, muscular pains, mental irritability, abdominal pain, gastro-enteritis, fatty degeneration of the liver, and neuritis. The work of Bradley and Fredrick[26] reveals as a result of animal experimentation such new features as eosinophilia, myocardial damage, nephritis, periportal fibrosis, with some increase in organ pigmentation.

Prevention and Treatment

The treatment for antimony emergency following oral intake is the same as that for arsenic. Industrial prevention obviously follows those lines practical for the prevention of lead poisoning. The constant eosinophilia found in animals possibly may constitute a diagnostic feature in examinations of exposed industrial workers. Antimony may be detected in the urine, skin and hair. The well known *Marsh test* properly applied may distinguish between arsenic and antimony.

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"Fit to-Fly," the handbook of Grow and Armstrong[13] is written in popular style and dedicated primarily to the presentation of medical information which the flier should know to protect his life and health.

Bibliographies of aviation medicine are also now available[14a, 14b, 14c, 14d] or projected.[15]

ANOXIA AND THE USE OF OXYGEN

Critical Level for Oxygen Administration

Armstrong[1] in 1939 summarized the prevailing military regulation concerning the utilization of oxygen in flight:

> "At the present time all high altitude military airplanes in this country are provided with gaseous oxygen equipment and military personnel are required to utilize oxygen at all times while participating in flight above 15,000 feet; when remaining at an altitude below 15,000 feet but in excess of 12,000 feet for periods of two hours or longer duration, and when participating in flights below 12,000 feet but at or in excess of 10,000 feet for periods of six hours or longer duration."

Evidence has accumulated meanwhile to indicate that this altitude-time schedule places the critical level for oxygen administration too high. Accordingly there has been a growing tendency to recommend the administration of oxygen at lower altitudes, even for flights of short duration. The experimental data are from experiments on the effects of exposure to moderately lowered tensions of oxygen upon *cardiac function*, *vision*, and *mental functions*.

Largely because of the well-established individual variation in reaction to lowered oxygen tension and the appreciable handicap imposed by the use of oxygen breathing equipment, no unanimity of opinion on the critical level for oxygen administration has been reached. Dill[16] suggests that the level for beginning to breathe oxygen may be 7500 feet in the case of the civilian pilot, but as high as 15,000 feet for the military pilot. Behnke and Willmon[17] recall the time-intensity relationship which must be considered in evaluating the tolerance to low oxygen pressure. According to them prolonged exposures at 9000 feet may produce anoxia. Monaco[4] would begin the use of oxygen at 6000 feet, while Strughold[18] recommends 13,000 feet (4000 meters) as the proper level. Grow

and Armstrong[13] (p. 213) sound a warning against neglect of use of oxygen:

> "One of the bitter lessons learned in the present war in Europe has been that the airplane crews who fail to use their oxygen at moderate altitudes, and above, become easy prey for enemy planes and even bring about their own destruction by gross errors in judgment, mental lapses, lack of alertness, and undue fatigue. Most of those who have had a considerable amount of experience in that conflict insist on taking oxygen, beginning at 10,000 feet, especially when they have a difficult mission to perform or are going into combat, although it is not required by regulations until about 15,000 or 16,000 feet is reached. This practice would seem to be justified by the fact that tests have shown a 6 to 10 per cent loss of efficiency at 12,000 feet which in combat would be just about the margin between victory and death."

Discussion of the altitude level for beginning oxygen administration has become academic where ascent to extremely high altitudes or night flight are concerned. Because of the hazard of aeroembolism in the former and the possible impairment of night vision in the latter case, the administration of oxygen from the start of ascent or before is indicated.

The Hazard from Carbon Monoxide

Another factor in favor of more extensive use of oxygen at lower altitudes is the protection thus afforded by efficient oxygen administration apparatus against exposure to carbon monoxide. Experiments of Douglas, Haldane, and Haldane[19, 20] demonstrated that the oxyhemoglobin left in the arterial blood when it is partially saturated with carbon monoxide has its dissociation curve altered in such a way that the hemoglobin binds the oxygen more firmly. The oxygen still present in oxyhemoglobin is therefore less easily available and the influence of carbon monoxide on oxygen supply to the tissues is enhanced. Thus carbon monoxide produces two effects upon the blood, *a reduction of circulating hemoglobin available for oxygen carriage* and *hindrance to the dissociation of oxyhemoglobin.*

Heim[21a, 21b] has discussed this dual effect of carbon monoxide on the blood and presents some estimates of its magnitude and influence upon altitude tolerance. Assuming that the dual action is double that of the oxygen displacement

effect, he calculates that the net result of a concentration of 0.005 per cent carbon monoxide would be equivalent to that of 0.01 per cent carbon monoxide, resulting in a maximum altitude tolerance of 7000 feet, as compared with an assumed altitude tolerance of 14,000 feet without carbon monoxide.

Obviously the handicap imposed by breathing oxygen in flight at lower altitudes must be weighed against the fact that concentrations of carbon monoxide without serious effects at sea level become dangerous at even moderate altitudes.[22]

Oxygen Poisoning

With increased frequency and duration of oxygen breathing the toxicity of oxygen for acute and chronic exposure has created concern. Further data defining the time-intensity relationship of the toxic effect of oxygen have been secured.

Behnke *et al.*[23] reported that *convulsions* or *syncope* developed in men after approximately forty minutes exposure to 4 atmospheres. J. B. S. Haldane[24] finds that five minutes exposure at 7 atmospheres is about the limit of toleration. Evidence has accumulated to indicate that there is relatively slight danger of development of serious symptoms of oxygen poisoning from exposures of duration reasonably to be expected in modern aerial operations, especially when oxygen is administered chiefly at low atmospheric pressures. Experiments on animals have shown apparently that the toxic effects at low atmospheric pressure are also proportional to tension and time of exposure, the chief injury being inflammatory changes in the lungs. No harmful effects appeared in susceptible animals after long exposures to pure oxygen at 425 mm. Hg pressure or below (Armstrong).

To validate these results for human beings, crucial experiments with men have been made by Clamann and Becker-Freyseng[25a, 25b] in Germany and Behnke in this country. Clamann and Becker-Freyseng exposed themselves for sixty-five hours to an atmosphere of 90 per cent oxygen, 10 per cent nitrogen at normal pressure. No ill effects were suffered by either subject during the first twenty-four hours. On the second day both subjects developed nervous disturbances (paresthesias and paroxysmal tachycardia) and showed de-

creased vital capacity. One subject developed vomiting and "bronchitis" with fever. Symptoms persisted in both subjects for more than a week after termination of the experiment.

This experiment was subsequently repeated at a simulated altitude of approximately 29,250 feet (9000 meters). In this experiment the two men were as well after three days as they had been the first day. The only disturbance reported was flatulence, attributed to the mechanical effect of low pressure. Behnke[25] reports that men remain in good physical condition following exposure to 99 per cent oxygen for eleven hours, five of which were spent at ground level and six at 37,000 feet altitude equivalent. Behnke and Willmon[17] also report experiments in which 99 per cent oxygen has been breathed by man as long as eighteen hours without apparent harm. They note, however, that some pulmonary and nervous irritation was produced in certain experiments after six hours. In one case Behnke and Willmon describe sudden appearance of signs of acute allergy including nausea, formation of wheals, dermographia, and dermatitis attributed to inhalation of oxygen. These symptoms appeared in an individual who had previously breathed oxygen daily under increased barometric pressure for a period of several weeks without noticeable symptoms. Exacerbation of the dermatitis was produced after two weeks when oxygen was again administered. Strughold[15] concludes from the experiments of Clamann and Becker-Freyseng that the respiration of pure oxygen for the length of time required in aviation can have no harmful effects upon the health.

There is apparently considerable variation among individuals in *susceptibility* to the toxic effects of oxygen. Furthermore the symptoms attributed to long exposure to oxygen are of a very serious nature. The frequency of respiratory infections at certain seasons and the possibility that these may increase the susceptibility of the individual to the toxic effects of prolonged oxygen breathing have received little attention in evaluating the dangers of oxygen poisoning. Because of the foregoing considerations it is safe to say that the conclusion reached by Strughold will not generally be accepted until reinforced by further experience and research with human subjects.

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the last war in the administration of oxygen from a liquid oxygen supply.[27]

In spite of great improvements in apparatus for oxygen administration, the pipestem or some modification thereof was extensively used up to the outbreak of the present war, and is still used by pilots in this country. This is largely to be explained by the conservative tendencies of the fliers who were accustomed to the use of the pipestem and, in some cases, had experience with no other method of oxygen administration. Three factors have operated recently to overcome these tendencies and to stimulate routine use of more modern and efficient apparatus for oxygen administration: (1) the stringent necessity imposed by increased training and combat flights at very high altitude; (2) improved instruction and training of thousands of young recruits to aviation in the use and necessity of oxygen in flight; (3) and a campaign of education and publicity on the dangers of altitude exposure without oxygen in aviation.

Boothby and Lovelace[28] of the Mayo Clinic took a leading part in this campaign of education and in addition have developed one of the most widely used apparatus of the continuous flow type available at the start of the war. In 1938 they described this apparatus, which they had devised in conjunction with Dr. A. H. Bulbulian (*the B.L.B. oxygen inhalation apparatus*), and recommended its use for administration of oxygen to fliers. Other types of oxygen inhalation apparatus in which face masks are an essential part were available,* designed for specific uses such as mine rescue work,[29] emergency resuscitation, metabolic testing or therapeutic administration of oxygen.[30] It soon became apparent, however, that apparatus satisfactory for these purposes could not satisfy the more stringent requirements of high altitude flight.

The original model of the B.L.B. mask has undergone considerable modification,[31, 13] intended to overcome difficulties arising during exposure to intense cold and very low oxygen pressure at high altitude. The most important change is the

* Record-making altitude flights to altitudes over 35,000 feet without pressurized suits or cabins are prima facie evidence of the existence of efficiently functioning oxygen apparatus for high altitude flight prior to the more recent developments in this field.

No specific study has apparently been reported of the effects of *repeated intermittent exposures* to high oxygen concentrations at atmospheric or subatmospheric pressures such as may be required in daily flights to high altitude. On the other hand, evidence gained from experience now available does not indicate that harmful chronic or accumulative effects are to be anticipated.

"Paradox Effect" of Oxygen

Ruff and Strughold[2] and Becker-Freyseng and Clamann[25b] call attention to the very interesting "paradox effect" of oxygen administration. If pure oxygen is suddenly inhaled after exposure to lowered oxygen pressure severe enough to produce symptoms of anoxia, a temporary aggravation of the condition may occur with clonic convulsions, coma, or other signs of serious involvement of the central nervous system. Similar reactions have been observed in the author's laboratory and by others during animal experiments, when animals have been rapidly returned to atmospheric pressure after exposure to low pressures causing anoxia. It is possible that these two phenomena are both due to the same cause, *i.e., sudden increase in oxygen tension following anoxia.* These phenomena have obvious practical importance in view of the possibility that they may occur at a critical time when the taking of oxygen at altitude has been too long delayed, or on sudden descent due to failure of oxygen supply.

ADMINISTRATION OF OXYGEN

Development of Oxygen Breathing Equipment

During and immediately following the last war the necessity for the use of efficient oxygen administration apparatus by fliers was amply demonstrated. The dangers of the *oral method* were realized and recognized to be intensified by the necessity of flight at higher and higher altitudes. J. S. Haldane,[20] a pioneer in this as in many fields of applied physiology, devised a *mask* for economical oxygen administration to fliers. This had obvious defects, but proved to be a model for future development. It should be noted that masks were used by the Army Air Corps during the decade following

apparatus for all purposes. Poppen discusses in some detail the characteristics of two types of oxygen supply apparatus, the performance of which has not previously been critically examined in published material.

Lung Demand Apparatus

The stringent demands of high altitude combat flying have stimulated the development of automatic types of breathing equipment which do not require the pilot to regulate the flow of oxygen manually as he changes altitude. Economy is secured by a type of regulator which permits the flow of oxygen only during inspiration, interrupting the flow during exhalation and the intervening pause between inspirations. Concerning this very important development in oxygen breathing equipment, Poppen says:

> "Because of this intermittent flow, this type is more economical than the fixed flow valve type but it makes no provision for the percentage of oxygen not absorbed by the lungs, more than 85 per cent oxygen being exhaled to the open air.
>
> "The lung demand type interposes a number of stipulations which require very careful control and test criteria. They must function throughout a wide range of barometric and temperature variation. They must provide adequate partial pressure of oxygen up to the physiological ceiling. They must be capable of furnishing adequate rates of flow even under extreme exertion and peaks of inspiratory demand. They depend on both inspiratory and expiratory valves which must introduce a minimum resistance and must not freeze at very low temperature and moderate wind velocities. The lung demand type requires an absolutely leak-proof mask. If there is an inspiratory leak there will be dilution by ambient air. If there are expiratory leaks, there is increased chance for frostbite and loss of economy through failure to close the lung demand valve. They must be provided with emergency by-passes."

The Rebreather Apparatus

Poppen[33] also considers the self-contained type of oxygen breathing equipment (the rebreather) for use in military flying:

> ". . . There are two general types. In one the system is entirely closed except for a manually operated exhaust valve. Exhalation is through a canister which absorbs oxygen and moisture (and incidentally generates a small amount of oxygen) into the breathing bag. As the rebreathing volume is depleted by absorption of oxygen in excess of that generated, the deficiency is made up by the opening of a valve from an oxygen supply system. This may be an integrally attached flask or a central low

use of a mask covering both nose and mouth, the so-called *oronasal mask*. Rate of flow in this device is not automatically regulated according to demand but by a manually operated flow regulator calibrated in thousands of feet altitude. Automatic regulators for continuous flow systems have been available since the last war. An automatic regulator of this type with superimposed manual control has recently been described.[32]

Criteria for Oxygen Administration Apparatus

A noteworthy advance in this field of aviation medicine has been the formulation of requirements for oxygen administration apparatus to be used in high altitude flight. This formulation is based upon accumulated practical experience in flight, physiological and physical tests in the laboratory, and theoretical considerations. Certain general principles have become clear and likewise the necessity for appraisal of each piece of apparatus in the light of the altitude exposure, special duties, activity level and other characteristics of its user.

Armstrong[1] in 1939 outlined criteria for an ideal method of oxygen administration in flight, noting at the same time that "up to the present no method of oxygen administration has even remotely approached this ideal and there appears to be little chance that such will ever be attained."

The Committee on Aviation Medicine of the National Research Council has also formulated an extensive set of desiderata and criteria for testing proposed oxygen breathing apparatus.[33]

Poppen[5] has emphasized additional specifications: comfort, lightness of weight, oxygen economy, delivery of as close to 100 per cent oxygen as possible, simplicity, ruggedness, and automatic function under all circumstances without frequent control or adjustment. In a later publication Poppen[33] describes the various types of oxygen supply systems used for military flying and presents a critical discussion of each type. He emphasizes the need for selecting the type of apparatus best suited to the particular needs of the flier and his task, since it has not been found desirable to settle on one type of

The problem of oxygen supply and administration in aviation steers between the Scylla of economy of space and weight and the Charybdis of safety. We may anticipate with some assurance that engineering developments will eventually relegate this problem to a subordinate position. Adequate heating of airplanes, pressurizing of enclosed cabins[33a, 33b] or of pilot suits, new methods for providing a more plentiful supply of oxygen, will solve many of the most urgent of the problems of protection of fliers against oxygen deficiency. Meanwhile the war in the air will be fought by airmen using oxygen apparatus and to a certain extent the outcome will be determined by the efficiency of that apparatus.

Oxygen Supply Equipment in Current Use

Poppen[33] describes the types of oxygen supply equipment being used by the air services today:

". . . From information which reaches us through liaison channels, it may be said that, in general, European combatants are using models of the following types of equipment: The R.A.F. is using a type of free flow apparatus which can be adjusted for different altitudes and does not re-require a leak-proof sealed mask. They are making rapid progress in the development and extension to service of more economical equipment, better fitting masks and means for providing oxygen. The Luftwaffe has profited by their years of peace-time preparation and has the best equipment in service use today. They have concentrated on a lung demand type which is characteristically well designed and built, is very efficient and foolproof, has been perfected by years of meticulous research and extreme service proving and could be profitably copied by any air service. In our service we are well equipped with oxygen apparatus. The Navy uses a lung demand type and the Navy rebreather. They are quite satisfactory. The Army Air Forces are using a rate of flow regulator which is meeting service needs."

A recent Canadian article[36] outlines the experience of the R.C.A.F. with oxygen problems:

"From many trials made at high altitudes it was found that the B.L.B. oxygen mask (standard U. S. pattern) was not an efficient unit for high altitude or service work. Similar trials made with the R.A.F. mask (Type E) likewise showed an operating deficiency at extremely high altitudes. This was due to the small size of the economizer bag.

"The Medical Directorate tested these masks, as well as German service masks in a low temperature room. It was found that the B.L.B. mask froze up very quickly at low temperatures and that the R.A.F. mask was similarly deficient. Reports from England in this connection confirmed our

pressure supply system which may be tapped at a number of positions distributed throughout the aircraft. This is by far the most economical of all oxygen breathing apparatus. . . .

"Another type of rebreather provides for the elimination of nitrogen by constant bleeding of a portion of the rebreathing volume. For this reason it is not so economical as the completely closed circuit type. The oxygen is forcibly circulated by an injector in the oxygen supply line."

So far as the apparatus itself is concerned, operation must be efficient at the lowest temperature apt to be encountered in service, viz. about −65° F., allowing some margin for safety. So far as the user is concerned the ultimate requirement is that the arterial oxygen saturation[34] shall be maintained at a figure above the critical value of 80 per cent saturation up to altitudes as high as 40,000 feet. Above this altitude, pressure must be applied by means of a closed cabin or a pressure suit to maintain the alveolar oxygen pressure within safe limits. Short flights may possibly be made above this altitude, but here, as in the case of lower altitudes without oxygen, the time-intensity effect determines the limits of tolerance. Various authorities give various figures for the limiting altitude for flight without added external barometric pressure while breathing 100 per cent oxygen in the range from 30,000 to 40,000 feet and above. The exact level is dependent on the altitude tolerance of the individual exposed, the length of exposure, and level of activity.

Limitations Imposed by Mask Usage

The wearing of a mask imposes certain restrictions on respiration which practically must be held within certain *quantitative* limits, *i.e.*, resistance to inhalation and exhalation, rate of supply of oxygen, and automatic variability of rate of supply to conform to demand, especially in exercise. Maintenance of normal breathing (for the test altitude) and protection against leakage or accumulation of nitrogen or carbon dioxide are further requirements. The comfort of the user must be considered especially in respect to the provision of a warm and moistened supply of oxygen. Conditions of use, such as temperature and rate of air flow and demand for economy of space and weight, determine important items of the specifications for oxygen apparatus.

of aeroembolism and it is generally agreed that these are similar to the symptoms experienced by workers in high pressure. *Bends* are the most commonly observed symptom, varying from mild to severe incapacitating pain in muscles, bones or joints. As in the case of bends in caisson workers, the pain, usually dull and aching in character, develops gradually and frequently is the only symptom noticed. *Paresthesias* of the skin are also frequently observed, including transient sensations of heat and cold. Itching and irritation of the skin occur, occasionally severe enough to produce dermatitis. Recompression usually affords complete and prompt relief from pain and paresthesias.

More serious symptoms relating to the lungs and the central nervous system have occasionally been reported. A condition has been observed similar to *divers' chokes* and attributed to embolism from gas bubbles accumulated in the pulmonary vessels. Various degrees of dyspnea, substernal distress, and cough are associated with this symptom. In aviators as in divers or caisson workers, this symptom is a serious one demanding immediate treatment. More rarely very serious symptoms of involvement of the central nervous system have been noted. Armstrong reports cases in which convulsions and motor paralysis were observed at 37,500 and 35,000 feet, respectively. Relief of symptoms was secured by recompression.

Divers and caisson workers with compressed air illness, especially when inadequately treated, develop numbness and weakness in the extremities. Vertigo (the "staggers"), nausea and vomiting and cyanosis may appear, followed by collapse and coma. Recovery following recompression treatment or spontaneously may take weeks during which anesthesia and paralysis, especially of the lower extremities, persist. In some cases paralysis of varying degree is permanent and the characteristic syndrome of *divers' palsy* appears. The symptomatology of divers' palsy is based upon permanent damage to the central nervous system, presumably due to pressure from gas bubbles or localized anoxia, and varies according to the extent and location of the lesions. Loss of bladder control and a characteristic scissors gait are frequently observed. Other

findings and it was obvious that a modification of a service mask was urgent."

The systematic instruction and training of flying personnel in the theoretical and practical aspects of the use of apparatus for oxygen administration may be recorded as a recent advance in aviation medicine. This program has a dual purpose —to select those men well adapted to flight at high altitude and to give practice and confidence in the use of oxygen apparatus. The success of this program depends to a large extent on *standardization of oxygen equipment.* The establishment of requirements for oxygen equipment and the training of large numbers of men in the use of this equipment constitute steps in the direction of improvement and standardization.

AEROEMBOLISM IN AVIATION

Definition

"The foundations of our scientific knowledge of the physiological effects of high and low atmospheric pressures were laid broad and firm by the investigations of Paul Bert" (Haldane[20]). The possibility that decompression sickness or caisson disease due to air embolism could occur in decompression from sea level pressure to low atmospheric pressures prevailing at high altitudes has been often suggested. Armstrong[1] appears to have been the first in this country to explore this possibility systematically. He distinguishes between compressed air illness arising from decompression after exposure to super-atmospheric pressures and the similar condition arising from reduction of pressure to fractions of an atmosphere. The latter he calls aeroembolism. In the light of present information this distinction appears to have little value, but the convenient term aeroembolism has been generally adopted to describe the syndrome of *bends* as it occurs in decompression to subatmospheric pressures, especially in flight at high altitude.

Symptoms of Aeroembolism

Industrial physicians will recognize here a new occupational cause for an old industrial disease. Armstrong,[1] Behnke,[26] Streltsov[37] and others have described the symptoms

that fifty-five men, or almost 7 per cent of 800 subjected to barometric pressure of 197 mm. and less (equivalent to about 32,500–47,000 feet altitude) complained of joint pains. Behnke found that twenty-eight subjects out of sixty divers and aviators withstood exposure for one hour at altitudes of 34,000 to 40,000 feet without symptoms. The remaining thirty-two, however, developed bends (and occasionally pulmonary symptoms) within the hour period. It should be noted, however, that *fatigue* of severe degree has been frequently reported following flights to high altitude, as well as exposure to simulated altitudes.

Factors Determining Occurrence of Aeroembolism

The factors which determine the occurrence of aeroembolism relate on the one hand to the environment and on the other hand to the physical characteristics and physiological status of the exposed individual. The rate of ascent (pressure decrease), the altitude attained, the duration of exposure (and possibly the temperature) define the critical conditions of the environment for causation of the manifest symptoms of aeroembolism. Biological factors relating to the individual are not so well established. Obesity (with body weight and build as indices*) appears to be most important. Age, recent previous exposure, circulatory and respiratory efficiency, prior treatment for removal of nitrogen, and certain other imponderable factors contribute to definition of individual susceptibility.

On the basis of his own low pressure chamber experiments Armstrong concluded that the possibility of the development of serious symptoms from aeroembolism was slight in ascents to altitudes below 30,000 feet. He indicated, nevertheless, that an extremely slow rate of ascent above 18,000 feet was required in order to preclude the possibility of development of bends in ascents to altitudes above 30,000 feet.

Influence of Altitude and Time.—Systematic observations on divers and aviators[26] have served to outline the critical conditions of altitude and time of exposure required to pro-

* Behnke, Feen and Welham propose specific gravity of the body determined by hydrostatic weighing as an index of obesity.[39]

sensory and motor disturbances are seen, indicating extensive damage to sensory and motor conducting tracts or neurones in the spinal cord or the brain. The first case of permanent paralysis or injury to the central nervous system from decompression to high altitudes or high altitude equivalent pressures apparently has yet to be reported.

The ability of the pilot or experimenter to gain relief from early symptoms by descent to regions of higher atmospheric pressure and the fatal consequences to be expected from really serious symptoms occurring at high altitudes in flight may account for this apparent difference between aeroembolism and caisson disease. As the frequency and duration of high altitude flights increase, flight surgeons will pay increasing attention to the possibility of the occurrence of aeroembolism with complications involving the central nervous system.

In addition to the foregoing trio of symptoms Behnke has described a fourth which may be designated as *decompression fatigue*. Fatigue of a severe, sometimes disabling nature has been observed to develop following decompression from higher to lower pressures in divers and in subjects exposed to simulated high altitudes. Associated with the bends or preceding development of pain, this fatigue is attributed to embolism and is prevented by adequate oxygen treatment before decompression. A delayed onset and cumulative effect of repeated exposures were noted.

Incidence of Aeroembolism

Many experienced flight surgeons until recently were inclined to consider the study of aeroembolism as much ado about nothing, since they had never encountered the condition in their previous experience.[38] They were also skeptical because of the considerable difficulty in differentiating some symptoms of aeroembolism from the familiar symptoms of aeroanoxia and pilot fatigue. Statistics on the incidence of aeroembolism are scanty. Few clinical cases have been described, and none in detail. Fulton and Streltsov mention the occurrence of aeroembolism as a result of exposure during actual flight, but available data appear to be based entirely upon tests at low pressures in decompression chambers. Streltsov reports

Certainly it seems difficult to accept the explanation of Streltsov in view of the similarity of bends in aeroembolism and in caisson workers where there is no reason for appearance of primary anoxia of the central nervous system.

Treatment

In the matter of treatment the aviator with aeroembolism has a distinct advantage over the caisson worker or diver with bends. For the latter, return to the usual environment at normal atmospheric pressure may induce symptoms, while for the aviator this constitutes more or less effective treatment. In all cases of mild aeroembolism reported hitherto it appears that recompression induced by descent to an altitude below the critical range produces complete relief of all symptoms except fatigue. In some cases of severe aeroembolism recovery has been considerably delayed after return to atmospheric pressure. Attempts to relieve these residual symptoms, especially the severe fatigue, by the obvious expedient of compression to slightly higher than atmospheric pressures have not been reported.

Oxygen inhalation with exercise has been used as a preventive measure, but not, apparently, in treatment. Severe cases may be expected to require compression combined with oxygen treatment. R. R. Jones *et al.*[39] have demonstrated the efficacy of oxygen treatment prior to decompression in the prevention of "bends" in caisson workers. A total of 3884 decompressions with oxygen were performed under careful supervision without a single case of caisson disease. Less carefully supervised decompressions with oxygen, numbering 11,196 prevented the development of severe caisson disease and held the incidence of cases of moderate or mild bends to a low figure.

Preoxygenation as a Preventive Measure.—Preventive measures have proved most effective in the attempts to solve the problem of aeroembolism. *Denitrogenation* by inhalation of pure oxygen prior to ascent has proved to be the most effective method. There are numerous testimonials in the literature to the general efficacy of this procedure, especially when combined with exercise, in preventing or delaying the onset

duce symptoms of aeroembolism. At a standard ascent rate of 5000 feet per minute without previous oxygen inhalation tests were made at 20,000 feet for four hours without ill effects; at 20,000–25,000 feet without manifest symptoms, but with fatigue on subsequent ascent to 35,000 feet. Mild bends were observed at 25,000–28,000 feet in a four-hour stay or on subsequent decompression to 35,000 feet. These data do not support the definition of 30,000 feet as the critical altitude level for aeroembolism, but indicate rather the customary time-intensity relationship, with the critical level for manifest symptoms for a four-hour sojourn in the range from 25,000–28,000 feet. Behnke regards the altitude range from 20,000–25,000 feet as an area of silent bubble formation in which a stay of four hours may be *potentially provocative* of symptoms, especially if ascent is continued to higher levels. The earliest symptom to appear under these borderline conditions is fatigue; bends of increasing severity are encountered as the altitude-duration effect increases.

Diagnosis

The diagnosis of aeroembolism presents some difficulties not encountered in caisson disease because so many of the symptoms may occur as a result either of *primary anoxia* or *anoxia secondary to air embolism.* Special methods of diagnosis apparently have not been developed. The earliest occurring symptoms typical of the bends are readily recognized, although each case may be to some extent complicated by fatigue or anoxia due to other causes. The origin of the pain typical of bends is uncertain.

Streltsov[37] suggests that it may be due to the influence of anoxemia in raising the susceptibility of sensory centers in the central nervous system to painful afferent impulses. Others have ascribed the pain of bends to pressure from gas bubbles present in the central nervous system, nerve trunks, tendon sheaths and joint spaces. Behnke believes that the pain typical of the bends is the result of ischemia of bony tissue produced by embolic occlusion of blood vessels in the bones. In support of this view Behnke cites reports of the occurrence of characteristic lesions in bone tissues in caisson workers.

bolism in those operations where fliers are required to remain at high altitude for short periods of time and can schedule flights to allow the preoxygenation procedure. In many cases this may not be feasible and it has become necessary to resort to other methods of control of aeroembolism. Use of a very slow rate of ascent is obviously impracticable, and really amounts to continuous decompression with oxygen. It is hard to see what advantage this could have over stage decompression or sea level denitrogenation.

The methods which have been tried or suggested to supplement or substitute for preoxygenation include selection of flying personnel for specific resistance to aeroembolism, maintenance of general physical fitness, control of diet, and special measures for protection from cold and other fatigue-inducing stimuli. *Decompression tests* in low-pressure chambers have been recommended for the selection of all fliers required to ascend to altitudes above 30,000 feet. Behnke proposes a test of one hour at altitudes between 30,000–40,000 feet without preoxygenation before ascent for all would-be fighter pilots.

Too little is known as yet about *variation in susceptibility* to aeroembolism between individuals and in the same individual on different occasions to evaluate the usefulness of this procedure. Susceptibility to bends is apparently related not only to weight and size, but also to the general physical condition of the individual. It would appear that final solution of the problem of aeroembolism has not been achieved. As in the case of the problem of acceleration and centrifugal force, effective control may be maintained by a judicious combination of the preventive measures now available.

Use of Helium-Oxygen Mixtures.—Two additional proposed methods for control of aeroembolism deserve mention. Behnke and others have proposed the use of helium-oxygen mixtures to replace atmospheric air as the respired gas in the waiting rooms in which high altitude fliers remain on call prior to ascent. It is claimed that the five-hour period of oxygen inhalation necessary to allow a stay at 37,000 feet for six hours without aeroembolism can be shortened to *ninety minutes* in the case of subjects thus denitrogenated and sat-

of aeroembolism during exposure to very low atmospheric pressures.[3a, 26, 31] Denitrogenation schedules required for prevention of aeroembolism in given altitude at specified time exposures have lately been elaborated in systematic tests and published.[40] Tables 1 and 2 summarize the results of these

TABLE 1

PRELIMINARY OXYGEN INHALATION AT SEA LEVEL BEFORE FINAL DECOMPRESSION*

(Rate of Ascent = 5000 feet per minute)

Duration of O_2 Inhalation	0	45′	90′	180′	300′
Allowed Exposure Without Aeroembolism (Altitude x Time)	20,000 x 240′ to 25,000 x 240′	29,000 x 240′ to 30,000 x 240′	34,000 x 240′	37,000 x 120′	37,000 x 360′ to 40,000 x 120′ (?)

* From data of Behnke.[23]

experiments. The subjects studied were chiefly divers, aged between 29 and 42 years, with an average age of 33 years.

From these figures it appears that an approximately three- to four-hour period of oxygen inhalation in the range from sea level to 20,000 feet is required to permit a stay of two

TABLE 2

PRELIMINARY OXYGEN INHALATION AT SEA LEVEL AND ALTITUDE BEFORE FINAL DECOMPRESSION*

(Rate of Ascent = 5000 feet per minute)

Durations of O_2 Inhalation at Sea Level and Altitude (Altitude x Time)	Sea Level x 0 + 20,000 x 240′	Sea Level x 0 + 25,000 x 240′	Sea Level x 45′ + 30,000 x 240′	Sea Level x 90′ + 34,000 x 240′	Sea Level x 0 + 20,000 x 300′
Allowed Exposure at Final Altitude Without Aeroembolism (Altitude x Time)	35,000 x 120′	35,000 x 120′ (?)	35,000 x 120′	35,000 x 120′	37,000 x 240′

* From data of Behnke.[23]

hours at 35,000 to 37,000 feet. A full five-hour period of preoxygenation is indicated for operations at 37,000 feet lasting four or more hours. The exact extent to which this schedule can be improved by the combination of exercise with oxygen inhalation apparently has not been determined. Preoxygenation may suffice to solve the problem of aeroem-

bolism in those operations where fliers are required to remain at high altitude for short periods of time and can schedule flights to allow the preoxygenation procedure. In many cases this may not be feasible and it has become necessary to resort to other methods of control of aeroembolism. Use of a very slow rate of ascent is obviously impracticable, and really amounts to continuous decompression with oxygen. It is hard to see what advantage this could have over stage decompression or sea level denitrogenation.

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urated with helium. Finally it may be repeated that present indications point to the engineering method of compressing, *i.e., supercharging* the ambient atmosphere of the high altitude flier, as the ultimate solution of most of the major problems of aviation medicine, including aeroembolism.

FATIGUE AND SELECTION OF PERSONNEL FOR FLYING

Factors Producing Pilot Fatigue

McFarland[9] has recently reviewed at length the question of fatigue among pilots of aircraft. The point was emphasized that fatigue and exhaustion often observed in fliers is out of proportion to the physical exertion involved in their work and must be ascribed chiefly to psychologic factors such as emotional stress based upon a wide variety of causes. McFarland discusses the role of noise, vibration, glare, lack of oxygen, and other factors including the regime of life and habits of pilots in the production of fatigue. Lack of exercise, poor selection of food, and excessive use of alcohol and tobacco are cited as causes tending to produce increased susceptibility to fatigue in pilots. McFarland and Edwards[41] failed to find convincing objective evidence of fatigue or decreased physical efficiency in seventeen fliers studied during trans-Pacific commercial air transport operations, although subjective feelings of fatigue were registered by the subjects.

It is regrettable that our review of the recent literature has not revealed any systematic and detailed study of fatigue among fliers subjected to the strain of flight operations in combat or patrol duties. There has been some skepticism concerning the importance of pilot fatigue and its relation to the actual experience of flying. It is to be hoped that the circumstances of combat and training in the war will yield more specific information contributing to our understanding of pilot fatigue.

Experimental Studies of Fatigue

A comprehensive study of a type of fatigue which appears to be closely related to that experienced by fliers has been made by Jones, Flinn, Hammond, *et al.*[42] Some of the results

of this study are considered to have application to the problem of fatigue of fliers and, to some extent, to the problem of selection of flying personnel. A survey of methods previously used or recommended for the study of fatigue was made. Certain familiar tests were adopted unchanged, others were used after modification, and some test methods not previously employed in the study of fatigue among large numbers of

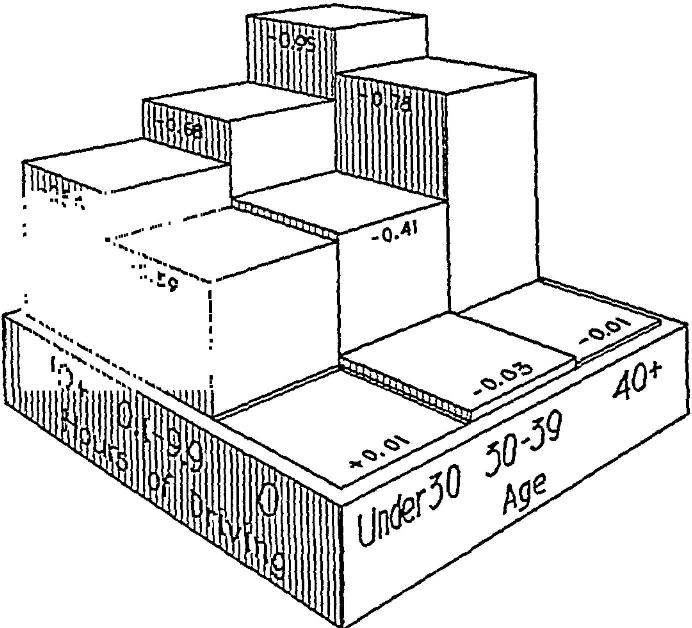

Fig. 177.—Fatigue of truck drivers. Combined effects of age and hours of driving as shown by coefficients of scoring. (Reproduced from Public Health Bulletin No. 265, Fatigue and Hours of Service of Interstate Truck Drivers.)

subjects were used. Certain of these tests were sufficiently promising to indicate their possible usefulness in the study of pilot fatigue, where the occupational strain is more intense than in the case of the truck driver. Among these are a test of the speed of eye movement, measured by means of a modified ophthalmograph; the determination of the critical fusion frequency of flicker; the leukocyte count, and a battery of simple psychomotor tests. In view of the relationship of an-

oxia to retinal sensitivity, the flicker fusion test is of special interest in aviators, since it may serve as an index of visual fatigue at the retinal level.

This study also demonstrated clearly the complex nature of fatigue, and showed again the futility of expecting to find a single reliable test for fatigue. The proposal was advanced that fatigue is a complex state of disturbed equilibrium which may be most profitably classified and studied in the same way as a clinical syndrome. The term "fatigue" is to be applied only on the basis of a combination of factors established by several selected tests and expressed as a composite and quantitative fatigue rating. The necessary statistical method to supplement this technic has been provided in the coefficient of scoring which gives a numerical composite score by means of which the general status of individuals may be classified when a set of tests of different functions has been given.

Age and Susceptibility to Fatigue.—It was found that truck drivers as a group are relatively young men. Psychomotor tests were given to 632 men, of whom only 90 were 40 years old or older. Analysis of the results indicated an additive effect of age upon stress-inducing experience (hours of driving in this case) in the production of fatigue. Figure 177 shows the mean coefficients of scoring by hours of driving since major sleep for men under 30 years of age, 30–39 years of age, and 40 years of age or older. In the case of men who had not driven at all since a major sleep there was no appreciable age trend, the mean coefficients of scoring being +0.01, −0.03, and −0.01, respectively, for the age groups under 30, 30–39, and 40 and over. In the case of men who had driven 0.1–9.9 hours, the mean coefficient of scoring was about the same for the men under 30 years of age (mean coefficient of scoring = −0.39) and men 30–39 years of age (mean coefficient of scoring = −0.41), while the men 40 years old or older showed a lower average functional efficiency on these tests (mean coefficient of scoring = −0.78). The *critical ratio* of the difference in the mean coefficient of scoring between the men under 30 years of age and the men 40 years old or older is $\frac{0.78-0.39}{0.16} = 2.44$. In the case of men who had

driven ten or more hours since major sleep, the age trend is more marked, the mean coefficients of scoring being -0.54, -0.68, and -0.95, respectively, for men under 30, 30–39, and 40 or more years of age. The critical ratio of the difference between the under-30-years-of-age group and the 40-or-more-years-of-age group is $\frac{0.95-0.54}{0.16} = 2.56$, which indicates a statistically significant difference.

This correlation of age and fatigability indicates the advisability of assigning *younger* men to those flying duties which are especially apt to cause great fatigue.

Selection of Flying Personnel

Selection of flying personnel, always one of the most difficult problems of aviation medicine, has today become one of the most pressing, because of the demands of rapidly expanding military and naval air forces. During the last war and immediately thereafter a great deal of effort was devoted to the investigation of methods to detect aptitude for flying. A multitude of sensorimotor and psychomotor tests were invented and tried. Much attention was paid to the classification of men by altitude reactions, *i.e.*, resistance to anoxia. Physiological tests for physical fitness were devised and standardized, some of which are still in use today.

The general medical requirements and criteria defining fitness to fly have gradually been improved. Assuming an unlimited supply of candidates for flying training, nonspecific selection on the basis of general physical fitness is no longer considered a particularly serious problem. The difficulty centers on the one hand about the extent to which existing standards may safely be relaxed in order to provide the large number of candidates required for training, and on the other hand about the problem of eliminating from training at the earliest possible stage those candidates who are doomed to failure in their efforts to qualify as pilots. In normal times, according to Grow and Armstrong,[13] the percentage of failures amounts to approximately 50 per cent, and it is obvious that improvement of this score would be extremely valuable in accelerating the pilot training program.

Pilot Selection Tests

Recent research on pilot selection has been a repetition, to some extent, of work done in the last war,[43, 44] but with greatly improved technical methods. Interest in behavior during exposure to oxygen deficiency has been renewed because of the necessity for flight at altitudes where inhalation of pure oxygen will not entirely prevent anoxia. A determined search is being made for methods which will *predict* flying ability and altitude stability of flying personnel. Almost every technical method at hand has been investigated for this purpose under various conditions of simulated altitude or oxygen deficiency.

The *electroencephalogram* has been recommended as an adjunct to the general physical examination to help eliminate candidates with epileptoid abnormalities and as a possible predictive method for revealing flying ability.[45] Armstrong[1] considers the *Mashburn serial reaction time test* as a promising method of assessing potential aptitude for success in flight training on the basis of the correlation between scores obtained with this method by students in the Army Air Corps Flying School and success in graduating from the School. Bigelow[46] advocates the *Rorschach method* as a possible aid in evaluation of aptitude for successful flight training and points out the advantage which it offers of objectivity.

Postural tests for circulatory efficiency, especially the tilt-table test, have been investigated in relation to determination of fitness to fly. Graybiel and McFarland[47] suggest the use of this method for selection of fliers, particularly for duties involving unusual circulatory stress, as in dive bombing.

Limitations of Selection Tests.—The present situation may be summarized by the statement that intensive research for better methods to reveal physical defects and predict aptitude for flying is being conducted; and attempts are being made to provide objective and quantitative criteria of flight performance against which the results of tests may be evaluated. The problem of selection presents many points of similarity to the problem of fatigue. It is, however, vastly more difficult because the methods employed are required to separate into groups, according to special standards of physiological or psychological fitness, individuals already specially set apart

by methods often only slightly less refined. Furthermore there is no equally convenient quantitative standard of reference against which to test the data obtained corresponding to hours of work or hourly production rate usually available in the study of fatigue. Perhaps greater progress in the problem of pilot selection would be made if more attention were devoted to systematizing the reports of instructors in order to make the ratings assigned more useful for comparison with other data. The search for a single predictive test is likely to be as futile here as in the problem of fatigue. Data of selection tests may assume more significance when treated to give a composite score along the lines of the coefficient of scoring to which reference has been made.

Selective Tests for Specific Duties.—In the absence of highly reliable methods of selection there has been a decided tendency to accept the *trial by ordeal* method for the early stages of training.[48] Subsequently those candidates who have demonstrated the ability to fly are subjected to more specific selective methods at different levels of training. These tests are again trials by ordeal and consist in subjecting the candidate as nearly as possible to the rigors and hazards of the actual conditions he will be required to withstand in his flying job. High altitude fliers are tested for resistance to cold and oxygen deficiency, and for susceptibility to *bends;* pilots of interceptor planes and dive bombers are tested for reactions to acceleration and centrifugal force; and pilots required to do night flying are tested for visual efficiency at low levels of illumination. Selection has become a continuous process, operating as it does in industry, by trial and error aided by more or less specific tests. In this process tests which are of little use in selection for training may prove useful in assigning pilots who have demonstrated ability to learn to fly to specific duties, *i.e.*, piloting of flying boats or large planes, rather than fast interceptor or scouting planes.

Conclusion

Progress in the problem of selection of flying personnel will be watched with attention by all interested in the human factor in industry. The difficulties of personnel selection and placement on every plane are epitomized by this problem of

aviation medicine. Current emphasis on the dramatic military aspects of aviation medicine has tended to obscure the fact that *aviation medicine* is a branch of *preventive medicine* of continuously increasing importance in public health. Specifically it belongs in the field of *industrial medicine*, with which it shares many problems, principles, and technical methods. Because of the intensity of occupational stress and the hazards to life and health involved in flying, in many cases these technics have reached their highest degree of development and application in aviation medicine. It is regrettable that aviation medicine in the United States has not been more closely identified in the past with industrial health activities. There can be no doubt, however, that the large amount of research and practical experience in aviation medicine arising from the present emergency will in future contribute substantially to advancement in the general field of industrial health.

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aviation medicine. Current emphasis on the dramatic military aspects of aviation medicine has tended to obscure the fact that *aviation medicine* is a branch of *preventive medicine* of continuously increasing importance in public health. Specifically it belongs in the field of *industrial medicine*, with which it shares many problems, principles, and technical methods. Because of the intensity of occupational stress and the hazards to life and health involved in flying, in many cases these technics have reached their highest degree of development and application in aviation medicine. It is regrettable that aviation medicine in the United States has not been more closely identified in the past with industrial health activities. There can be no doubt, however, that the large amount of research and practical experience in aviation medicine arising from the present emergency will in future contribute substantially to advancement in the general field of industrial health.

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